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The Seasonal Utilization of the Saskeram Marshes by Fish Populations and Its Significance to the Fisheries Resources of the Saskatchewan River Delta in Manitoba, with Special Reference to Northern Pike

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The seasonal utilization of the Saskeram Marshes by fish populations and its significance to the fisheries resources of the Saskatchewan River Delta in Manitoba, with special reference to northern pike.

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ABSTRACT

In recent years, frequent winterkills of fish have been witnessed in the Saskeram Marshes of the Saskatchewan River Delta. These winterkills were observed near control structures developed by Ducks Unlimited Canada to manage the marshes for waterfowl and muskrat production. Following some preliminary investigation in 1981 and 1982, an extensive study was conducted in 1983 and 1984 to examine the underlying causes of these winterkills and to detemine the relative merits of allowing fish access to the Saskeram Marshes.

Results of the present study, as well as observations from previous years, indicated that winterkills of fish in the Saskeram Marshes were associated with water releases from the upstream Cumberland Marshes, and notably from Cut Beaver Lake. This waterbody, which is utilized as a reservoir for the regulation of water levels in the various compartments of both the Cumberland and Saskeram marshes, receives continuous winter inflows from the Saskatchewan River sufficient to sustain fish populations throughout the entire year. Although a small mesh net is maintained as a barrier across the outlet of Cut Beaver Lake

during periods of water transfers, the net does not appear to be effective in preventing fish movements throughout the Cumberland Marshes or the transport of fish with waters diverted to the Saskeram Marshes via the Cumberland Dam.

The provision for fish movements into and out of the Saskeram Marshes resulted in a net gain in fish flesh to the Saskatchewan River. The preponderance of fish produced by the Saskeram Marshes consisted of northern pike. During 1983 and 1984, a total net weight of approximately 15,000 kg of pike was released from the marshes to the Saskatchewan River. Most of this production (~80%) consisted of young-of-the-year pike. The bulk of the young-of-the-year pike production is believed to have originated from the flooded sedge meadows fringing the Saskeram Lake area. Based on the two years of observation, the emigration of juvenile pike from the Saskeram Marshes just prior to freeze-up is a predictable event linked to temperature and oxygen conditions within the marshes.

In addition to the above major considerations, this report describes the fish populations which utilize the Saskeram Marshes, as well as general fish habitat conditions provided by the marshes. Recommendations are presented which are aimed at alleviating the extent of winter fishkills and enhancing conditions in the marshes for pike reproduction.

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INTRODUCTION

The present study deals with the fish resources of a portion of the extensive Saskatchewan River Delta. This Delta consists of two rather discreet areas (Fig. 1); a western portion which extends from the Squaw Rapids Hydroelectric Dam on the Saskatchewan River near Nipawin, Saskatchewan,to approximately The Pas, Manitoba, and an eastern portion extending from The Pas to the western shores of Cedar and Moose lakes. The two areas are separated by The Pas Moraine, a glacial end moraine which originates just north of The Pas, courses southeastward between Cedar Lake and Lake Winnipegosis and ends on Long Point, Lake Winnipeg (Klassen, 1983). A portion of the eastern Delta has been inundated by the forebay of the Grand Rapids Hydroelectric Dam, which is located at the mouth of the Saskathewan River. The western Saskatchewan River Delta can be divided into three relatively distinct areas. These are the Cumberland Marshes, which include wetlands lying between the Carrot River and Cumberland Lake and up to the Saskatchewan - Manitoba border, the Reader - Root Marshes which lie north of the Saskatchewan River and west of The Pas in Manitoba, and the Saskeram Marshes in Manitoba which are bounded by the Carrot and Saskatchewan rivers (Fig. 2). The area of the Cumberland Marshes is approximately 129,500 ha (Dunn 1982) of which about 42,500 ha (Mowbray and MacFarlane 1978) are regulated by Ducks Unlimited Canada for waterfowl and furbearer production.

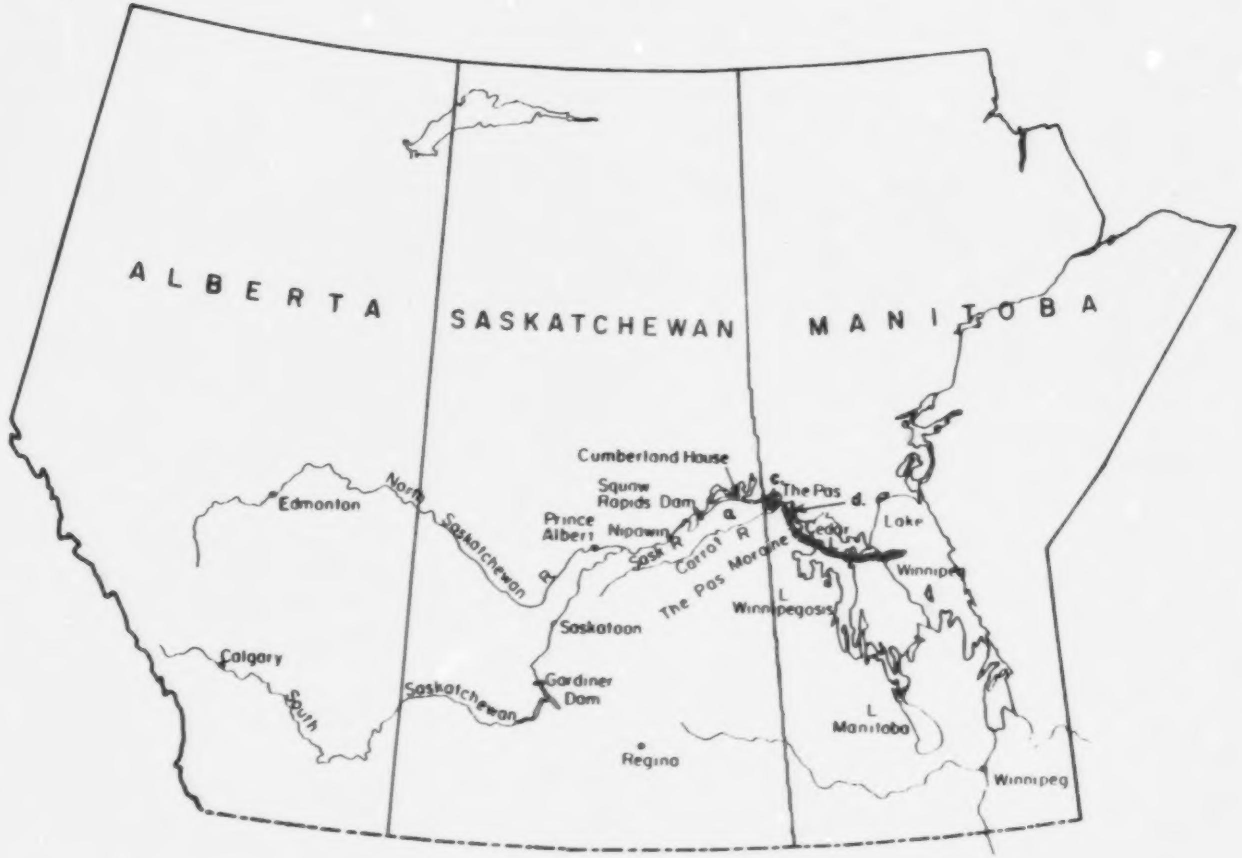
ALBERTA
SASKATCHEWAN
MANITOBA
Edmonton
North Saskatchewan R
Calgary
South Saskatchewan
Gardiner Dam
Saskatoon
Regina
Prince Albert
Nipawin
Squaw Rapids Dam
Cumberland House
Sask R
Carrot R
The Pas Moraine
a
b
c
d.
The Pas
Cedar L
L Winnipegosis
L Manitoba
Lake Winnipeg
Winnipeg

Fig.1. A map of the three Prairie Provinces showing the Saskatchewan River System and the location of the Cumberland Marshes (a), Saskeram Marshes (b), Reader-Root Marshes (c) and Summerberry Marshes (d).

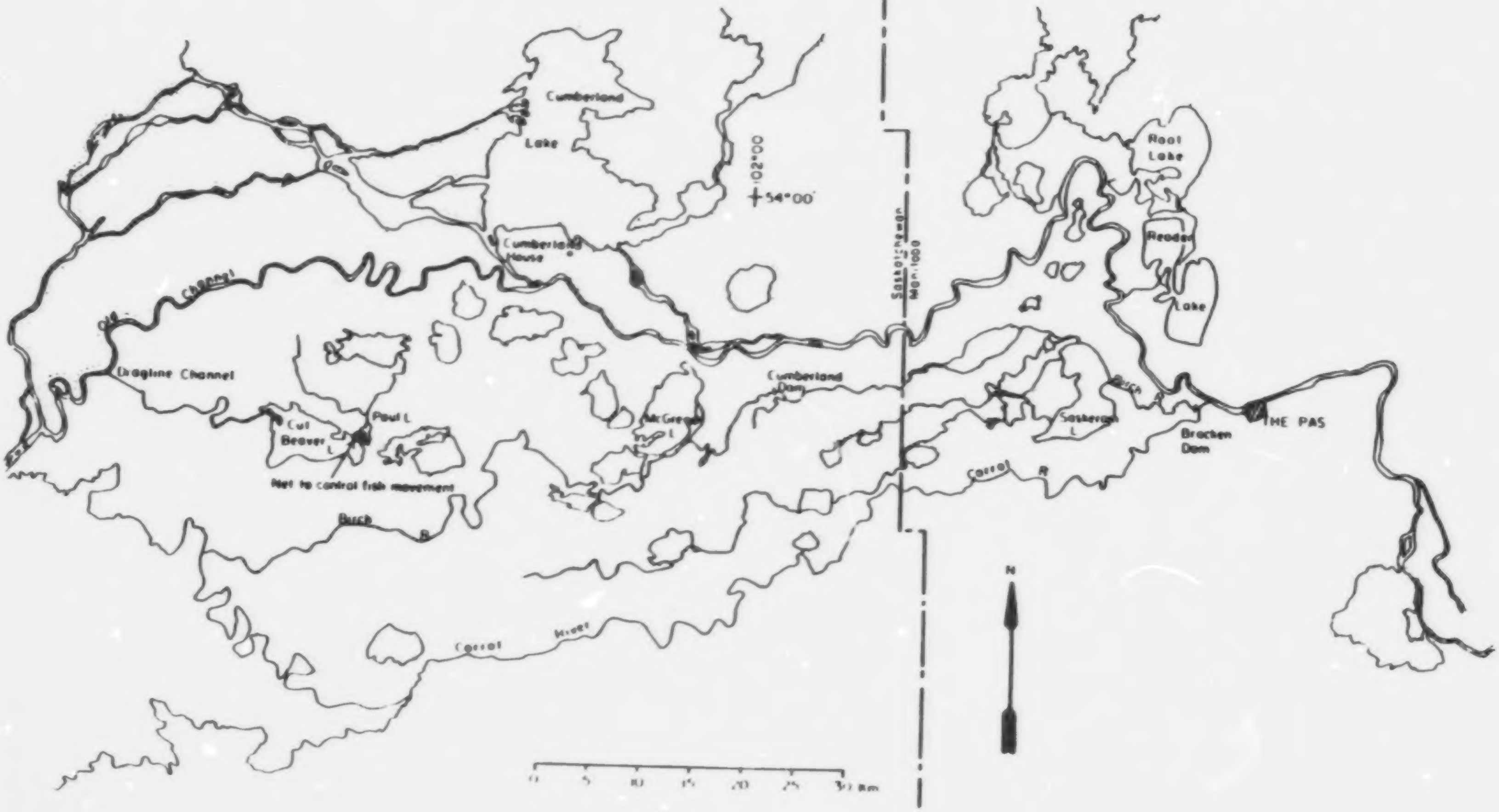
Cumberland
Lake
102°00'
54°00'
Cumberland House
Channel
Old
Dragline Channel
Cut Beaver L
Poul L
Net to control fish movement
Birch R
McGregor L
Cumberland Dam
Carrot River
Saskatchewan
Man.1000
Root Lake
Reader
Lake
Birch
Saskeram L
Carrot R
Bracken Dam
THE PAS
N
0 5 10 15 20 25 30 km

Fig. 2. The Cumberland and Saskeram marshes showing the major water control structures: Dragline Channel, Cumberland Dam and Bracken Dam.

The area specifically considered in this study is the Saskeram Marshes. However, reference will be made to a number of locations throughout the entire Saskatchewan River Delta since fish were not found to be restricted in their movements within the area. The Saskeram Marshes (Fig. 3), which are contained in the Saskeram Wildlife Management Area[1], have been managed for more than 40 years for the production of waterfowl and muskrats. Bracken Dam, which is located at the outlet of the Saskeram Marshes was first constructed by Ducks Unlimited in 1940 to regulate water levels in the marshes. This structure deteriorated to the state where it eventually had to be replaced. The existing control structure (Fig. 4) was completed by Ducks Unlimited in 1962. Between 1963 and 1973, several smaller control structures were built in the marshes.

There is little historical information on the utilization of the Saskeram Marshes by fish. At one time, as will be discussed later (page 17), flows through the area may have been much greater than now, and consequently the area would have been more suitable for fish. However, based on the sparse records that were kept in the more recent past, it does appear that the Saskeram Marshes and the Birch River, a major stream running through the marshes, were still of some importance to spawning stocks of fish. Prior to 1962, large numbers of walleyes moved into the lower Birch River and into the marshes. A record of personal observations made by a farmer who resided near the Bracken Dam for many years indicated that some 2500 walleyes were angled at the mouth of the Birch River in a 10 - day period during the spring 1961, and that at least as many walleyes had been taken from the area each spring since

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[1] The Saskeram Wildlife Management Area also includes the Reader-Root lake system.

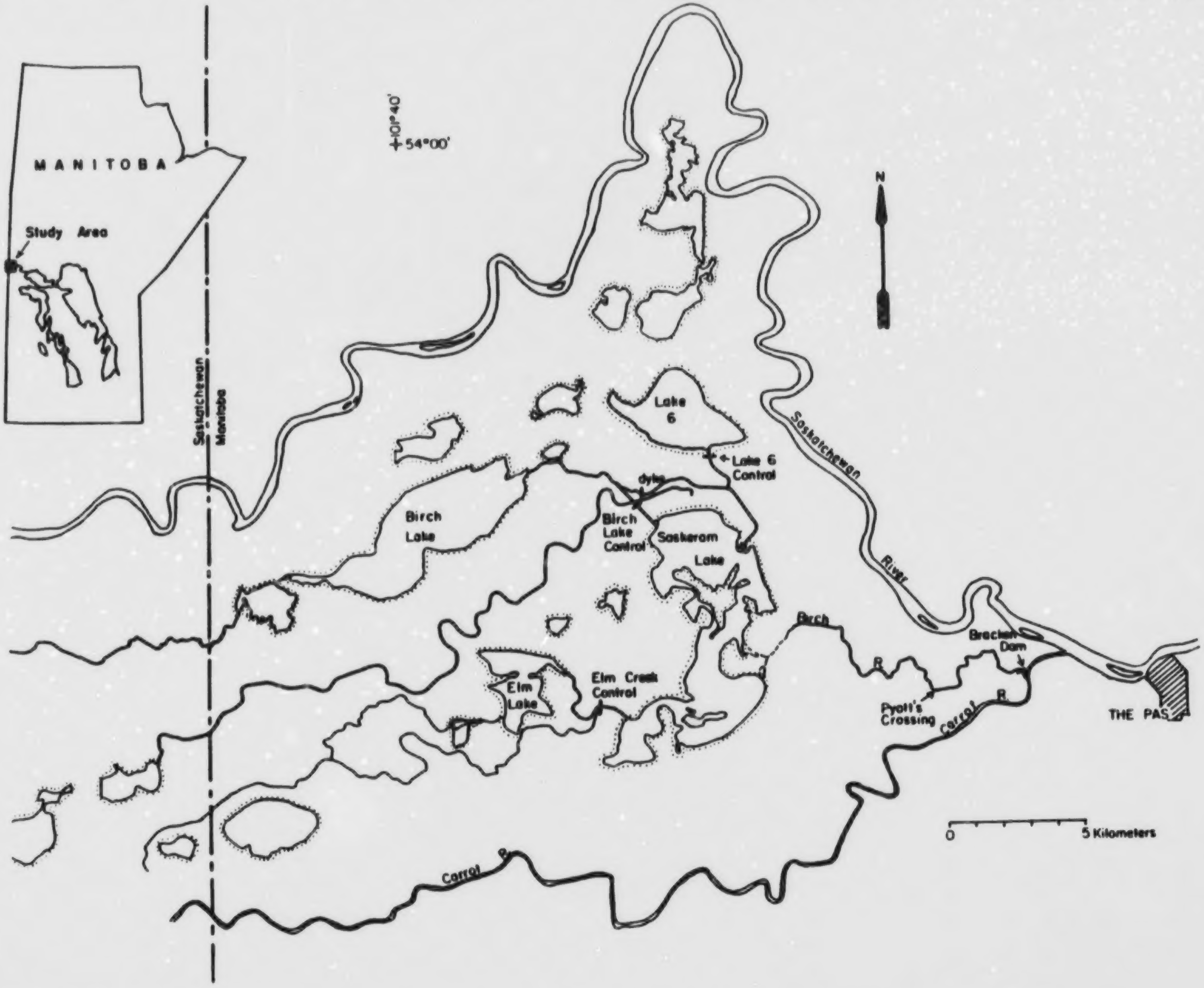
MANITOBA
Study Area
101°40'
54°00'
N
Saskatchewan
Manitoba
Saskatchewan River
Lake 6
Lake 6 Control
dyke
Birch Lake
Birch Lake Control
Saskeram Lake
Birch R
Elm Lake
Elm Creek Control
Pyott's Crossing
Brockman Dam
Carrol R
Carrol R
THE PAS
0
5 Kilometers

Fig. 3. The Saskeram Marshes study area showing the Ducks Unlimited control structures and major place names mentioned in the text.

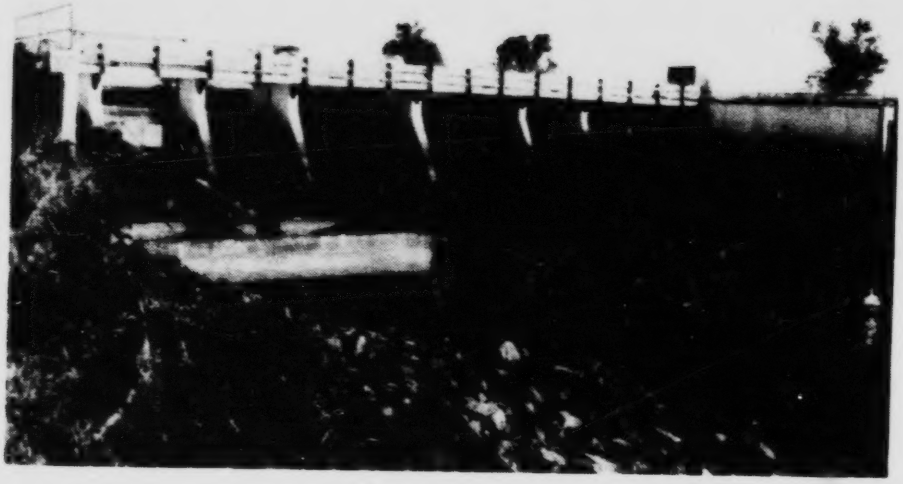

Fig. 4. Bracken Dam on the lower Birch River. Fish ladder is located to the left in the photo.

1940. R. Schlick (personal communication) noted that spring angling for walleyes was good during the 1960's in the Birch River at Pyott's Crossing, some distance upstream from Bracken Dam. Other species of fish have also been observed moving into the Saskeram Marshes to spawn. These included northern pike, white sucker, carp, and goldeyes.

According to available information, the old Bracken Dam did not, even in exceptionally low water years, maintain much more than a one metre differential between upstream water levels and the Carrot River. Walleyes and other spring spawning fishes were therefore able to surmount the barrier with little difficulty during the peak spring runoff period. At this time, outboard motorboats could safely move over the structure (G. Collins, personal communications). In 1964, two years after the existing Bracken Dam was constructed, a fishway was incorporated into the dam. For some years after, the fish ladder apparently was not required since spring water levels above and below the dam were almost equal. During this time, anglers going into the Saskeram Marshes could run their outboard motorboats through Bracken Dam with no difficulty (B. Wright, personal communication).

There are few early records of fishkills in the Saskeram Marshes. Conservation officer reports from 1960 or earlier indicated large numbers of dead pike, about 10 cm in length, during the late summer and early autumn when water levels in the marshes were receding. These fish were evidently young-of-the-year pike which had succumbed to summerkill conditions; i.e. a combination of high temperature and low dissolved oxygen. Sunde (1962) reported observing a similar summer die-off of pike in the Saskeram Lake area of the marshes. There are, however, no documented cases of winterkills of fish in the Saskeram Marshes prior to 1980. Although such events have undoubtedly occurred in the marshes for many years, the extent or severity of such winterkills are unknown. There is a possibility that winterkills prior to 1980 may not have been as frequent or as severe because of the manner in which the Saskeram Marshes were then managed. Before 1962, Bracken Dam was not high enough to permit sufficient impoundment of water in the autumn to prevent or impede the escapement of fish. Therefore, most adult fish which entered the marshes and their progeny where able to leave before freeze-up. After Bracken Dam was reconstructed in 1962, the Saskeram Marshes were still drained extensively in fall to provide staging areas for migrating waterfowl, and primarily geese. Under this management regime, many fish would be flushed from the marshes.

In 1978, Ducks Unlimited substantially altered its water management regime for the Saskeram Marshes. In that year, the Saskeram Lake area of the marsh was dewatered by drawdown and allowed to dry out so as to permit seed germination and regrowth of marsh plants in an area that was formerly open water. The area was then reflooded in the summer of 1979. The Saskeram Lake area was again drawn down in 1980 to allow haying operations during the summer. It was refilled in the autumn during the same year. Some fish from the Cumberland Marshes probably entered the Saskeram Marshes during this latter filling stage and subsequently fell victim to winterkill in the 1980/81 winter season. The first extensive winterkill recorded for the Saskeram Marshes was reported in February, 1981. A large number of dead pike, estimated in the thousands, was observed in the marshes at various locations (B. Wright, personal communication). Substantial numbers of dead adult pike were observed below Cumberland Dam. Winterkills in other areas of the Saskeram Marshes involved primarily juvenile pike.

As a result of the 1980/81 winterkill in the Saskeram Marshes, some controversy was generated over wetland projects developed or proposed in the area by Ducks Unlimited and the impacts of such projects on fish resources. The Inland Waters Directorate of Environment Canada, under instructions from the Prairie Provinces Water Board (PPWB), was already engaged in a 5 – year water quantity/quality study of the Cumberland Marshes. The objective of this study was to ascertain the impacts, if any, of the Cumberland Marshes Project upon water quality (Crosley 1985.). Following the February 1981 fishkill event, the PPWB requested that the water quality sampling be expanded to include the lower Birch River and the Saskeram Marshes (Dunn 1982). Fisheries investigations were also initiated at the same time. In May, 1981, regional staff of the Manitoba Fisheries Branch began a preliminary investigation of fish movements into the Saskeram Marshes at Bracken Dam. Fish production from the marsh was also considered. This study was continued in 1982 and results from the two years of study have been summarized and reported (Leroux 1982).

In 1982, agreement was reached between Ducks Unlimited and Fisheries Branch, Manitoba Department of Natural Resources, to conduct a jointly sponsored and more detailed two-year examination of fisheries aspects related to the wildlife management of the Saskeram Marshes. Under the agreement, field work was begun in May, 1983 and was virtually continuous on a daily basis until mid-December, 1983. Some sampling excursions were made into the marshes during the 1983-84 winter season. Specific objectives of the 1983 work were as follows:

1) To determine the magnitude and timing of upstream migration of spawning pike, walleyes, suckers, and other fish species into the Saskeram Marshes.
2) To determine the size of adult fish populations in the lower Birch River, their patterns of movement and the length of the residency within the marsh system.
3) To determine the escapement (i.e. production) of young-of-the-year of the major fish species from the marshes.
4) To determine dissolved oxygen concentrations and the presence or absence of the major fish species throughout the marshes during the 1983-84 wintr season.

In 1984, field work was begun in late April and continued on a daily basis until the end of November. The objectives were similar to those of 1983, except less effort was devoted to documenting movements of fish within the marsh system.

The overall objectives of the Saskeram Marshes fisheries study was to derive a point estimate of the net benefit (or loss) of fish biomass obtained from the area under the current operational regime employed by Ducks Unlimited. Based on the study findings, recommendations are made vis-a-vis water management in the Saskeram Marshes which will be aimed at a) reducing the frequency and severity of fish kills, b) mitigating unavoidable loss in fish biomass and c) increasing fisheries benefits from the area where possible.

DESCRIPTION OF THE STUDY AREA AND ASSOCIATED AREAS

The study area considered in this report is part of the Saskatchewan River Delta which lies in the western portion of the physiographic diversion known as the Central Lowlands of North America. Bedrock geology of much of the Saskatchewan River Delta consists of Silurian dolomite of the Paleozoic era. Cretaceous materials underly the western extremity (Teller and Bluemle 1983). The Delta is now basically a broad flat plain. The upper part, that is the portion encompassed by the Saskatchewan and Carrot rivers, drops from an elevation of 280 m ASL at Kennedy Creek to 260 m near The Pas, Manitoba, a distance of about 100 km (Dirschl 1972). Surficial material consists of alluvial and lacustrine sediments which began depositing some 10,000 years ago following the retreat of the Wisconsinan ice sheet and the formation of Lake Agassiz (Shreiner 1983). Exposure of these sediments with the draining of Lake Agassiz was not complete until about 7000 BP (Ritchie and Hadden 1975).

The Saskatchewan River Delta is approximately 48 km wide and 193 km long and extends from Tobin Lake near Nipiwan, Saskatchewan to the western shores of Cedar and Moose lakes in Manitoba (Royer 1966). The Delta is intersected by a prominent glacial feature, The Pas Moraine, at The Pas (Klassen 1983). From here, this end moraine follows a curving southeast course over the north end of Lake Winnipegosis ending on Long Point in Lake Winnipeg. The Saskatchewan River Delta east of The Pas

Moraine probably began forming some 8000 years ago when the Saskatchewan River cut a channel through the end moraine. At this time, the Saskatchewan River emptied into Lake Agassiz through the present channel occupied by the Minago River. This course probably allowed alluvial material to settle in the Summerberry Marshes area between the present day Cedar and Moose lakes, before the river veered northeastward to the Minago channel. If, at that time, the Saskatchewan River had occupied its existing channel, one would expect a deltaic formation in northern Lake Winnipeg.

The Saskatchewan River Delta is in a dynamic state due to the ongoing natural process of alluvial deposition. The Delta has undergone some major changes due to natural events. For example, an alteration in the course of the Saskatchewan River, as will be noted on page 17, greatly affected flow and deposition patterns in the Cumberland House area of Saskatchewan. With the increased settlement of the area, natural evolutionary processes in the Delta may have been modified by the cumulative affect of water management measures by agriculture and wildlife management agencies. Some examples of past water management efforts are the dyking, drainage and agricultural development of the Carrot River Valley and the regulation of the Cumberland and Summerberry marshes in the first part of this century for the production of muskrats. Changes may also be anticipated due to more recent, large scale, human intervention (Dirschl et al. 1967). Existing and proposed dams on the Saskatchewan River system in Alberta and Saskatchewan will affect the downstream transport of alluvium. The hydroelectric dam at Grand Rapids, for example, has significantly altered upstream sedimentation in the

Saskatchewan River Delta. This alteration has resulted in a two-fold increase in Secchi transparency on Cedar Lake (Derksen unpublished data).

The climate in the study area is of the Humid Continental - Cool Summer (Dfb) type under the Koppen classification (Dirschl 1972). The climate is typified by a relatively short growing season, low precipitation and a large variation between summer and winter temperatures. The frost-free period ranges from 100 to 110 days (Weir 1983). Mean annual precipitation at The Pas is 492 mm and the mean January and July daily temperatures are -22°C and 18.3 °C, respectively

Two main soil types occur within the Delta area (Weir 1983). These are the Cumulic Regosolic and Humid Gleysolic types. The first consists of imperfectly drained soils which lack specific profile development; they generally occur on recently deposited alluvium. Humid Gleysolic soils are found in areas subject to prolonged spring flooding and high groundwater tables. These soils have some profile development and possess a dark coloured A horizon. A detailed account of soils in the study area is presented by Ehrlich _et al_. (1960).

Because of the poorly drained soils and frequent flooding in the Saskatchewan River Delta, plant communities representative of marshes and bogs typify the vegetation in the study area. The wetland area may vary from open water with submergent plants to various mixtures of reeds, grasses, sedges and willows, depending upon the amount of water present. Water management by Ducks Unlimited in recent years has reduced the amount of open water (specifically Saskeram Lake) in the study area. On the drier sites, such as the river levees and bedrock outcroppings, stands of deciduous and coniferous trees occur. A more complete description of vegetation throughout the Saskatchewan River Delta may be found in Anonymous (1961), Townsend (1965), Dirschl et al. (1967), Dirschl and Dabbs (1969), Dirschl (1972), Dirschl and Coupland (1972) and Phillips (1980). Information on vegetation specific to the Saskeram Marshes study area can be found in Ould et al. (1979)

The compilation of water quality information on marshes within the Saskatchewan River Delta has begun only very recently. In 1979, the five-year water quantity/quality study of the Cumberland Marshes was undertaken by Ducks Unlimited and Environment Canada upon request for the Prairie Provinces Water Board. A final report of this study has been completed (Crosley 1985). As a result of the fishkill in the Saskeram Marshes in the 1980/81 winter season, and in conjunction with the above study, water quality samples were taken in the Saskeram Marshes from Cumberland Dam to Bracken Dam during February, 1982 (Dunn 1982). Other water quality information specific to the Saskeram Marshes has been recorded by Ould et al. (1979). The following description of water quality conditions in the study area and environs has been extracted from the above reports.

Water quality measurements on the inflow and outflow of the Cumberland Marshes reveal substantial changes in water chemistry within the marshes (Crosley 1985). These changes may vary to some degree depending upon the time of year and in accordance with the nature of water routing through the marshes. Sodium and chloride concentrations in 1984 were higher in the outflow of Cumberland Marshes than in the inflow. The inflow, however, possessed higher sulphate concentrations. Similarly total nitrogen, phosphorus and carbon concentrations were higher in the outflow of the Cumberland Marshes, particularly during the winter. Ould et al. (1979) provide very little water quality information on the Saskeram Marshes. They report the area to be moderately alkaline and having specific conductance values ranging from 170 to 1410 μS/cm[1]. Ould et al. (1979) speculated that high salinity levels originating from the Sipanok Channel could cause problems with aquatic vegetation and invertebrates if adequate dilution did not occur. Dunn (1982) provides a more comprehensive description of water quality in the Saskeram Marshes, although all of this information is based on winter (February, 1982) sampling. Examination of Dunn's (1982) data indicates that the nutrient content of waters flowing through the Saskeram Marshes is enhanced. Carbon and nitrogen levels reported for waters flowing into the Saskeram Marshes (Crosley 1985) are significantly lower than the mean levels found within the Saskeram Marshes. Carbon and nitrogen levels in the Saskeram Marshes are also higher than the concentrations reported for the Carrot River (Table 1). Dunn (1982) reports a mean specific conductance for the Saskeram Marshes of 1948 μS/cm. This compares to readings of 591 μS/cm just below Cumberland Dam to 1406 μS/cm below Saskeram Lake. Specific conductance of Elm Creek water just before it enters Saskeram Lake was 700 μS/cm. Elm Creek water was found to possess major ion concentrations (e.g. Na, Cl, Mg and Ca) 12 to 20 times higher than in the Birch River downstream of Cumberland Dam. These as well as high concentrations of TDS and dissolved nitrogen, suggest groundwater infusion to the Elm Creek system (Dunn 1982).

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[1] μS/cm = μmhos/cm

Table 1. Some water quality parameters recorded for the Birch River in the Saskeram Marshes during February, 1982, compared to the Carrot River (from Dunn 1982).

Parameter	Mean (mg/1)	Comments
Dissolved org. carbon	33.0	Conc. 2x higher than in Carrot River
Particulate org. carbon	8.1	Conc. 5x higher than in Carrot River
Total org. carbon	40.0	Conc. 2.5x higher than in Carrot River
Dissolved nitrogen	1.8	Conc. in Carrot River 0.75 mg/1
Particulate nitrogen	0.86	Conc. in Carrot River <0.01 mg/1

Because of high productivity of the Saskeram Marshes, the shallow water depths throughout most of the area and low flows, if any, during the winter months, oxygen depletion and anaerobia are a common winter occurrence. It appears from other studies (Dunn 1982, Crosley 1985), as well as the current investigation, that winter oxygen concentrations, sufficient to sustain some fish species, may be maintained for some time where there is moving water. At one time, the Saskeram and Cumberland marshes may have experienced much greater annual flows and been more suitable to fish than they are today. It has been reported that the area was used as a canoe route to Cumberland House, Saskatchewan, by early furtraders who wished to avoid the added distance and strong currents presented by the Saskatchewan River (Campbell 1950). There was a change about 1875 in the Saskatchewan River channel which reduced the flows through the Cumberland and Saskeram marshes. A huge ice jam in the Saskatchewan River west of Cumberland House, resulted in a new channel being cut to connect with the Sturgeon River (Peel 1972). Consequently, seventy-five per cent of the Saskatchewan River flow was diverted northward through Cumberland Lake. The Old Channel, as it is known, now carries only a quarter of its former flow volume. This reduction in flow has led to the Old Channel overtopping its banks and flooding the Cumberland Marshes less frequently. Infrequent flooding in the Cumberland Marshes in turn reduced their value as wetland habitat.

At the turn of the century, the Hudson Bay Company had jurisdiction over the Cumberland Marshes and utilized the area for muskrat fur production. In order to enhance water levels and fur production in the Cumberland Marshes, the Hudson Bay Company in the early

1930's dug Manpower Channel, a ditch connecting the Old Channel of the Saskatchewan River to the western part of the marshes. This channel soon silted in and was replaced in 1939 by Dragline Channel, a present day channel connecting the Old Channel and Cut Beaver Lake (Fig. 2). Around the same time, a wooden dam was built on the Birch River near the present site of the Cumberland Dam. This dam was built to elevate water levels on the Cumberland Marshes. In 1960, the Hudson Bay Company relinquished its rights to the Cumberland Marshes and Ducks Unlimited was granted a 15-year lease to improve and manage the area (Phillips 1980). In 1961, the Cumberland Dam was constructed to regulate outflow from the marshes. Two years later,a control structure was placed on Dragline Channel to regulate inflows to the Cut Beaver Lake, which is used as a storage reservoir for waters to be used in various cells of the Cumberland Marshes. If required, water from Cut Beaver Lake may also be routed almost directly to the Cumberland Dam for release into and regulation of the Saskeram Marshes. Since the early 1960's the regulation of water levels in the Cumberland Marshes has influenced flows downstream into the Saskeram Marshes.

Phillips (1983) reported that although the Old Channel of the Saskatchewan River presently carries only a fraction of its former volume, it may still periodically overtop the river levels and flood the Cumberland Marshes during spring run-off. The periodicity and volume of such overflows have been reduced due to man-made changes on the Saskatchewan River. The completion of major dams such as those near Outlook (Gardiner Dam) and Nipawin (Squaw Rapids Dam) have modified the flow patterns in the river. More particularly, high flows resulting from local spring run-off and later peak flows originating from snowmelt in the Rocky Mountains are now stored in Lake Diefenbaker (Gardiner Dam reservoir) and Tobin Lake (Squaw Rapids Dam reservoir). Discharges during the winter months are higher than under previous natural conditions. Examination of mean monthly discharges in the Saskatchewan River at Squaw Rapids and The Pas prior to and after 1962 (Fig. 5) illustrate the hydrographic effect of the dams. It should also be recognized that peak flows on the Saskatchewan River normally occurred in June and July and were coincident to the arrival of the mountain waters. Peak flows due to local run-off, as typified by the Carrot River hydrograph (Fig. 6), occurs in May under normal conditions.

High flows in the Saskatchewan River create backwater effects in the Carrot River which influences water levels in the Birch River below Bracken Dam. In some years, water levels may be high enough to cause a reverse head at Bracken Dam. Backflooding is normally prevented by increasing the stoplog elevation in the dam. The comparison of mean annual discharges in the Saskatchewan River at The Pas with the average annual heads experienced at Bracken Dam is shown in Fig. 7 over the period 1951-1984. This comparison reveals that at very high or very low flows an inverse relationship exists between the Bracken Dam water levels and Saskatchewan River flows. For example, during years when average flows in the Saskatchewan River exceed about 800 m^3 sec^{-1}, the difference in waters upstream and downstream is generally less than 0.5 m and in some years (i.e. 1951, 1953, 1954 and 1974) there may be no difference or even a reverse head. Dry conditions have been prevalent over the past decade and these have resulted in low water levels below

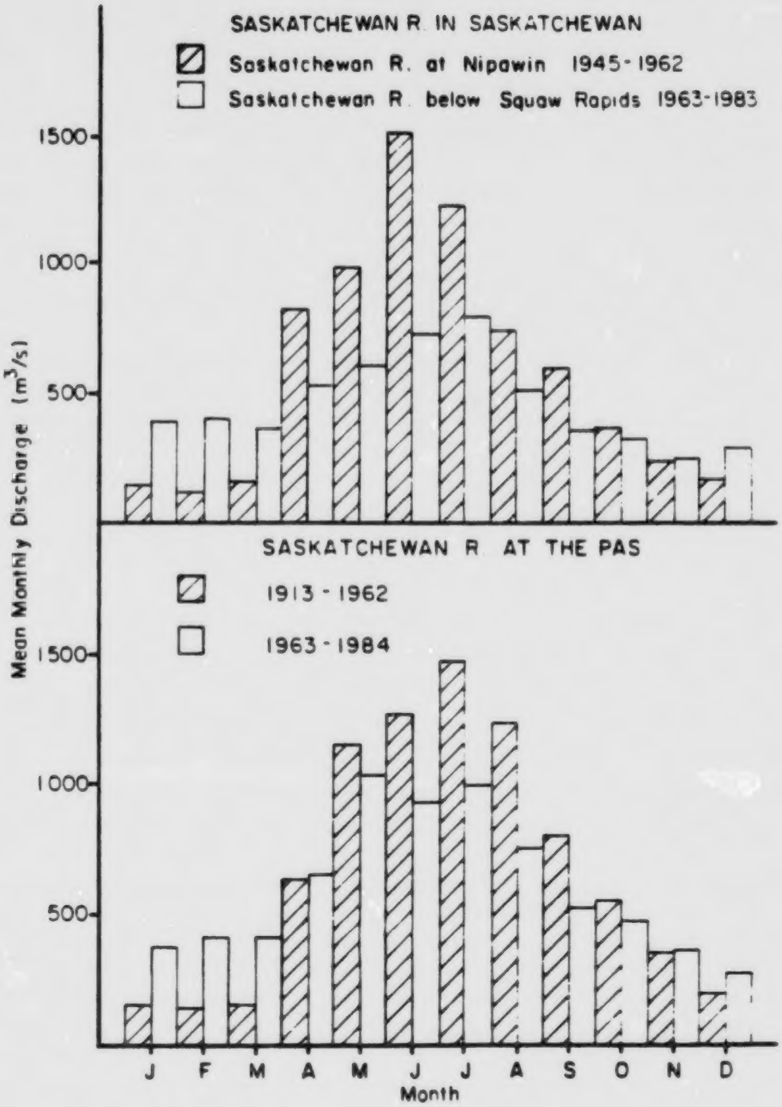

Fig. 5. Mean monthly discharges of the Saskatchewan River around Squaw Rapids and at The Pas before and after the completion of the Squaw Rapids Dam in the early 1960's.

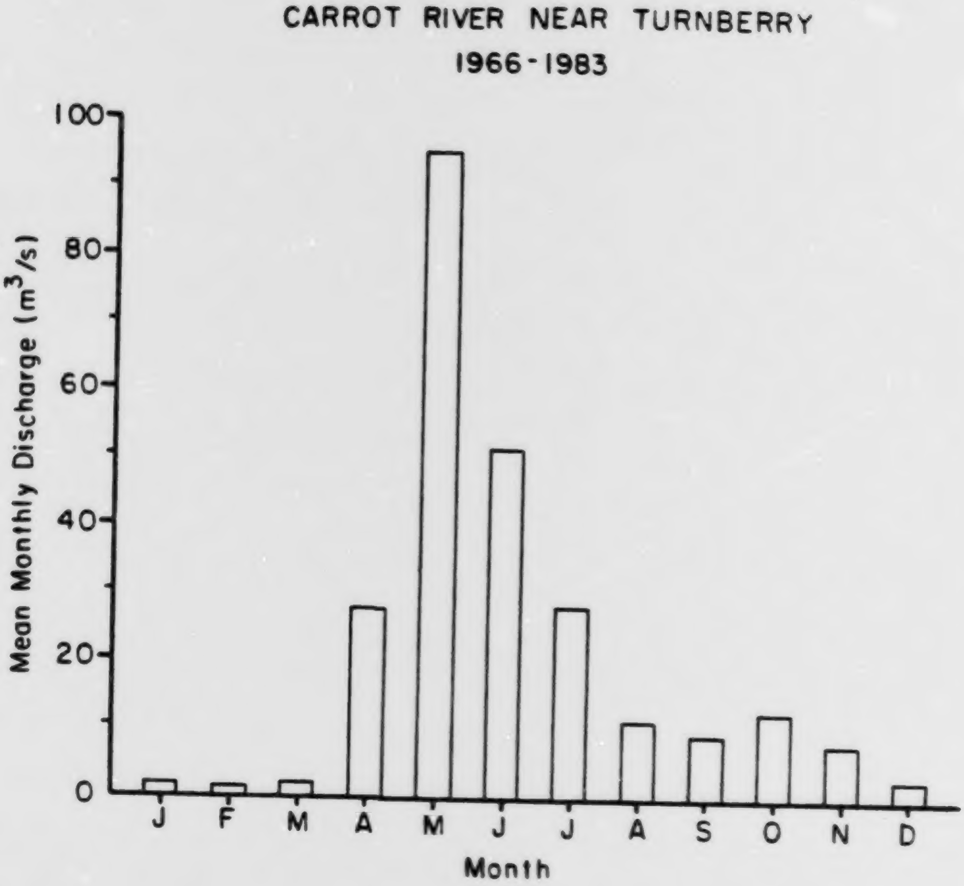

Fig. 6. Mean monthly discharges in the Carrot River near Turnberry, Maniotba during the period, 1966 - 1983.

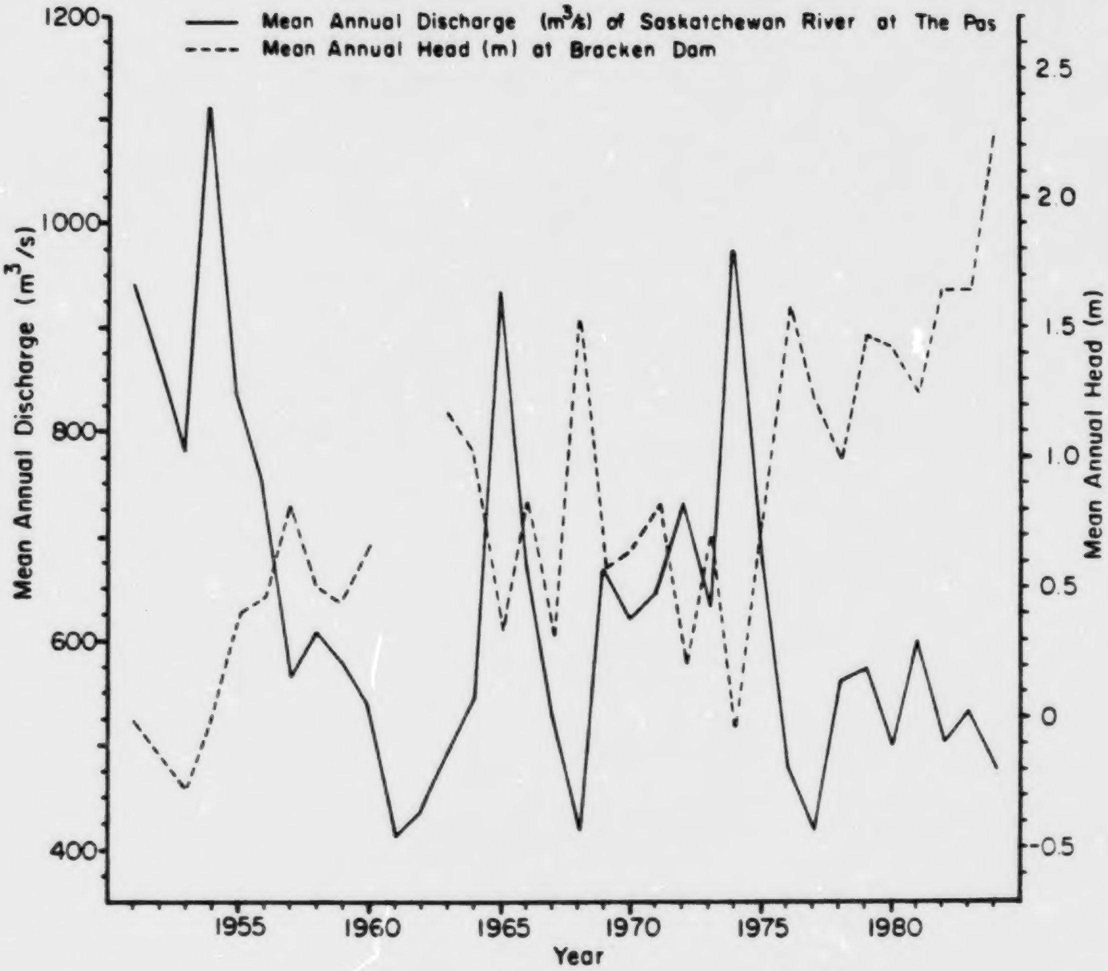

Fig. 7. Mean annual discharge of the Saskatchewan River at The Pas in relation to the mean annual heads at the Bracken Dam for the period, 1951 - 1984.

Bracken Dam. In recent years, the lowest flow conditions experienced on the Saskatchewan River were in 1984. After the spring run-off passed, water levels began dropping and reached the lowest level in the last six years (Fig. 8). Water levels dropped to a point where much of the river bottom below Bracken Dam was exposed (Fig. 9).

High flows on the Saskatchewan and Carrot rivers may under certain circumstances cause flooding of the Saskeram Marshes. Only exceptionally high flows in the Saskatchewan River, those with a return period of from 1-in-20 or 1-in-50 years, will cause flooding in the Saskeram Marshes (D. Flavell, personal communication). Flooding is more likely to come from the Elm Creek drainage or the Carrot River. Carrot River flows with a 1-in-6 year return period will cause backflooding into the Saskeram Marshes (Anonymous 1980).

Except in 1977 - 1979 when Saskeram Lake was in complete drawdown to permit revegetation, water levels in the area have been kept at or near the full supply level (FSL)[1] throughout the year. In most cases, local snowmelt and precipitation may be sufficient to maintain the FSL. Replacement water is required in years when precipitation is low and evaporation loss is high. Evaporation losses may occasionally exceed 30 cm (Anonymous 1980). Replacement water requirements may be taken, as indicated earlier, from either the Cumberland Marshes or from the Saskatchewan River via Cut Beaver Lake. In the latter case, water from Cut Beaver (or the Saskatchewan River) is routed through the southern part of the Cumberland Marshes, an almost direct route to Cumberland Dam. For example, a large volume of Saskatchewan River water was dumped into

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[1] FSL for Saskeram Lake is approximately 260 m above sea level. Water levels in areas upstream of Saskeram Lake are maintained at 260.6 m.

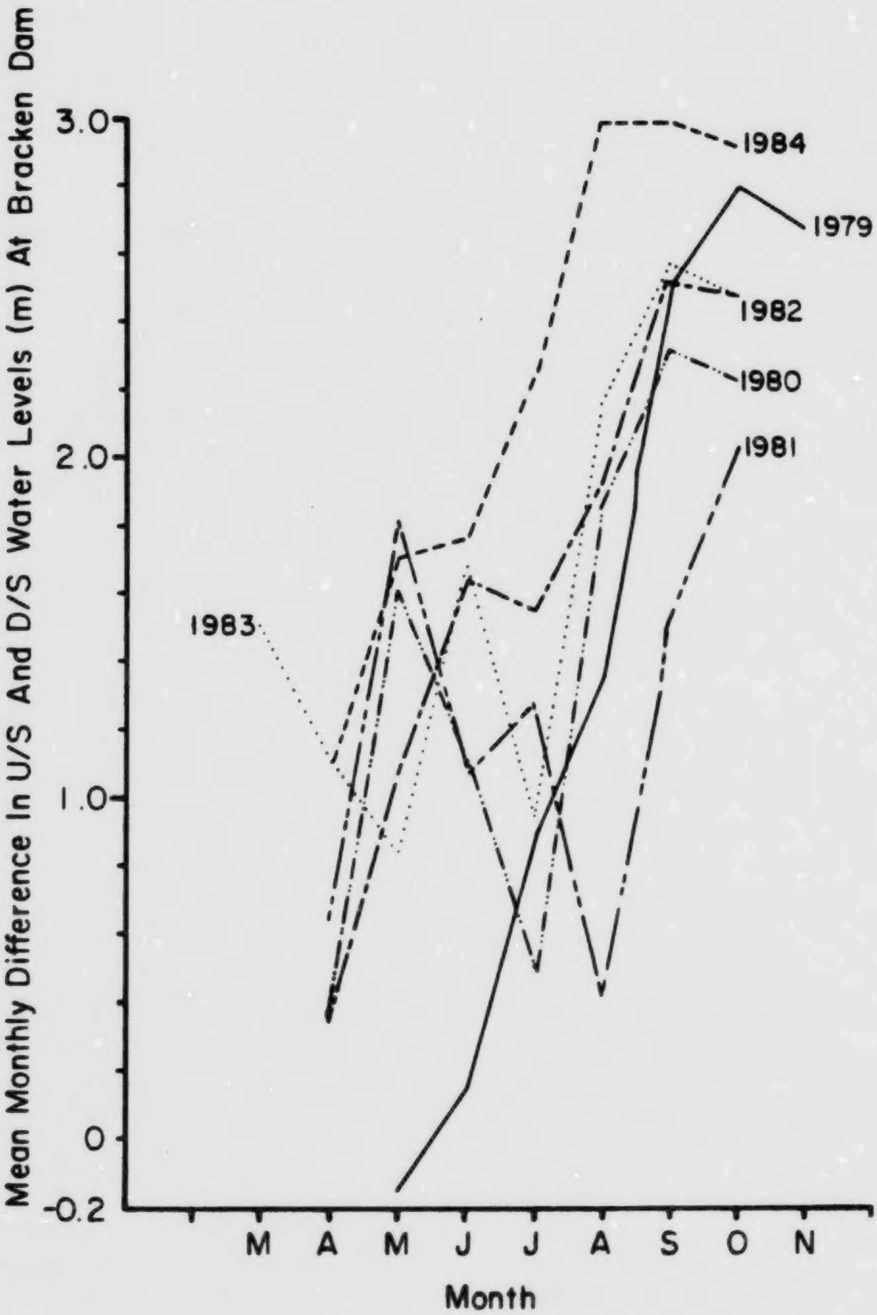

Fig. 8. Mean monthly differences in upstream and downstream water elevations at Bracken Dam during the openwater period for the years 1979 - 1984.

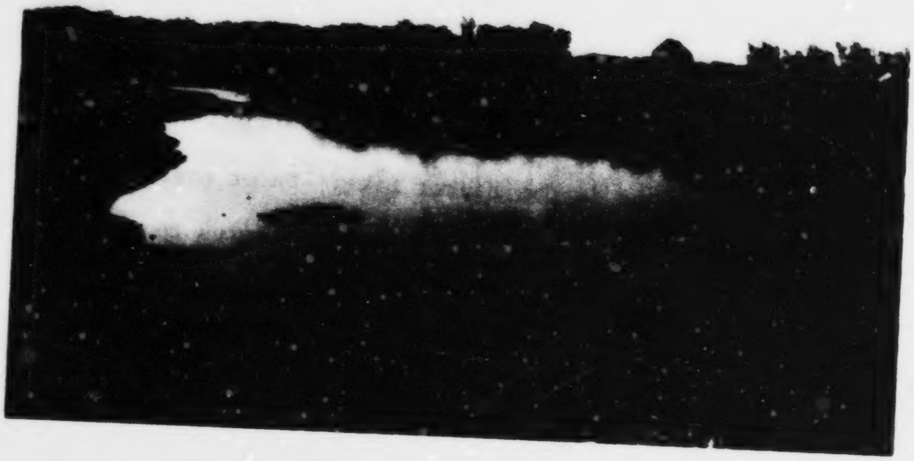

Fig. 9. Exposed streambed in the Birch River below Bracken Dam, September, 1984.

into the Saskeram Marshes in 1984, while in 1983, all water spilled at Cumberland Dam came internally (McGregor Lake) from the Cumberland Marshes. Total monthly discharges from the Cumberland Marshes through Cumberland Dam and into the Saskeram Marshes for the period 1980-84 are shown in Fig. 10. Engineering studies (Anonymous 1980) indicate that present flows in the Old Channel of the Saskatchewan River are adequate to maintain the desired water levels in both the Cumberland and Saskeram marshes. Discharges from the Saskatchewan River Old Channel to the Cumberland Marshes in recent years are presented in Fig. 11. It should be noted that since 1979, these discharges have been on a year-round basis. In 1979, fisheries management officials in Saskatchewan requested a minimum discharge of 0.84 m^3 sec^{-1} during the winter months to maintain fish populations in Cut Beaver Lake. Under present conditions any excess water in the Cumberland Marshes and surplus to needs in the Saskeram Marshes must still be routed through Saskeram Lake and over Bracken Dam. A Ducks Unlimited project is under construction which will permit flows from Cumberland Dam to bypass Saskeram Lake and empty directly into the Saskatchewan River. These works will allow for greater control over water levels in various parts of the Saskeram Marshes and particularly Saskeram Lake.

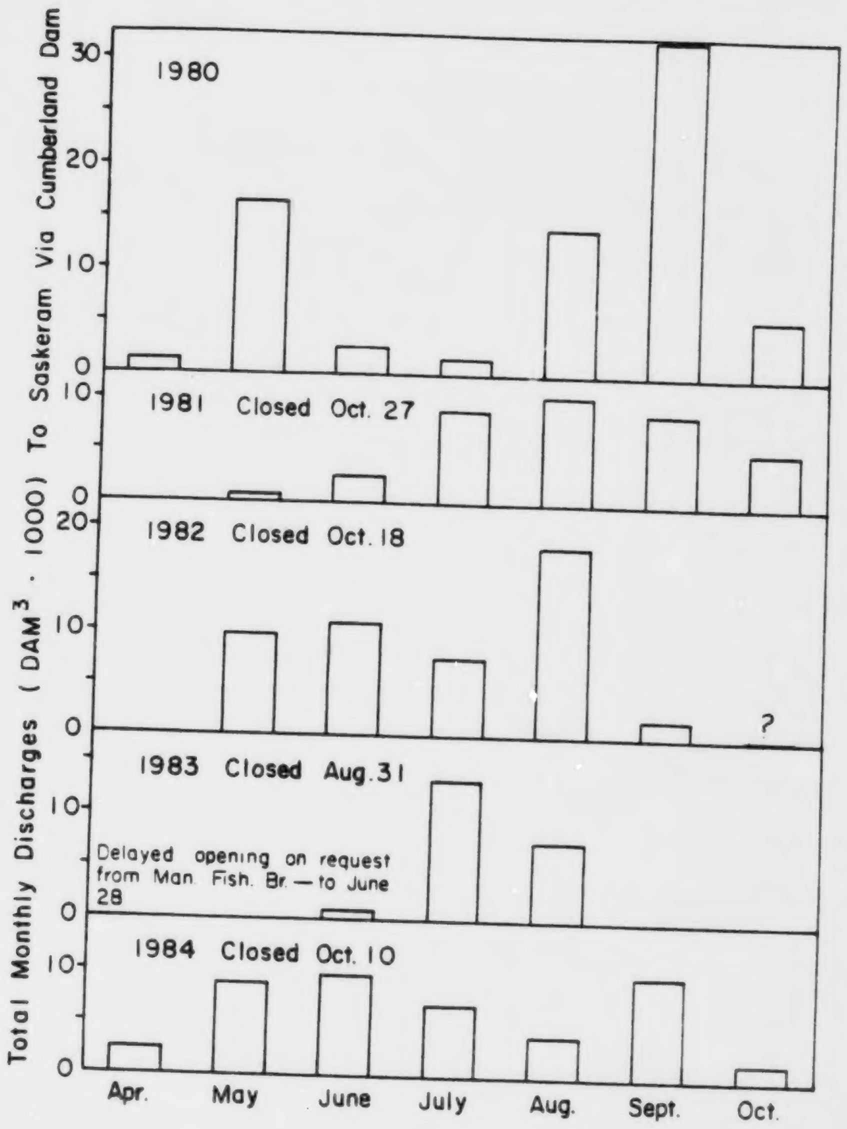

Fig. 10. Total monthly discharges from the Cumberland Marshes to the Saskeram Marshes via the Cumberland Dam for the years, 1980-1984.

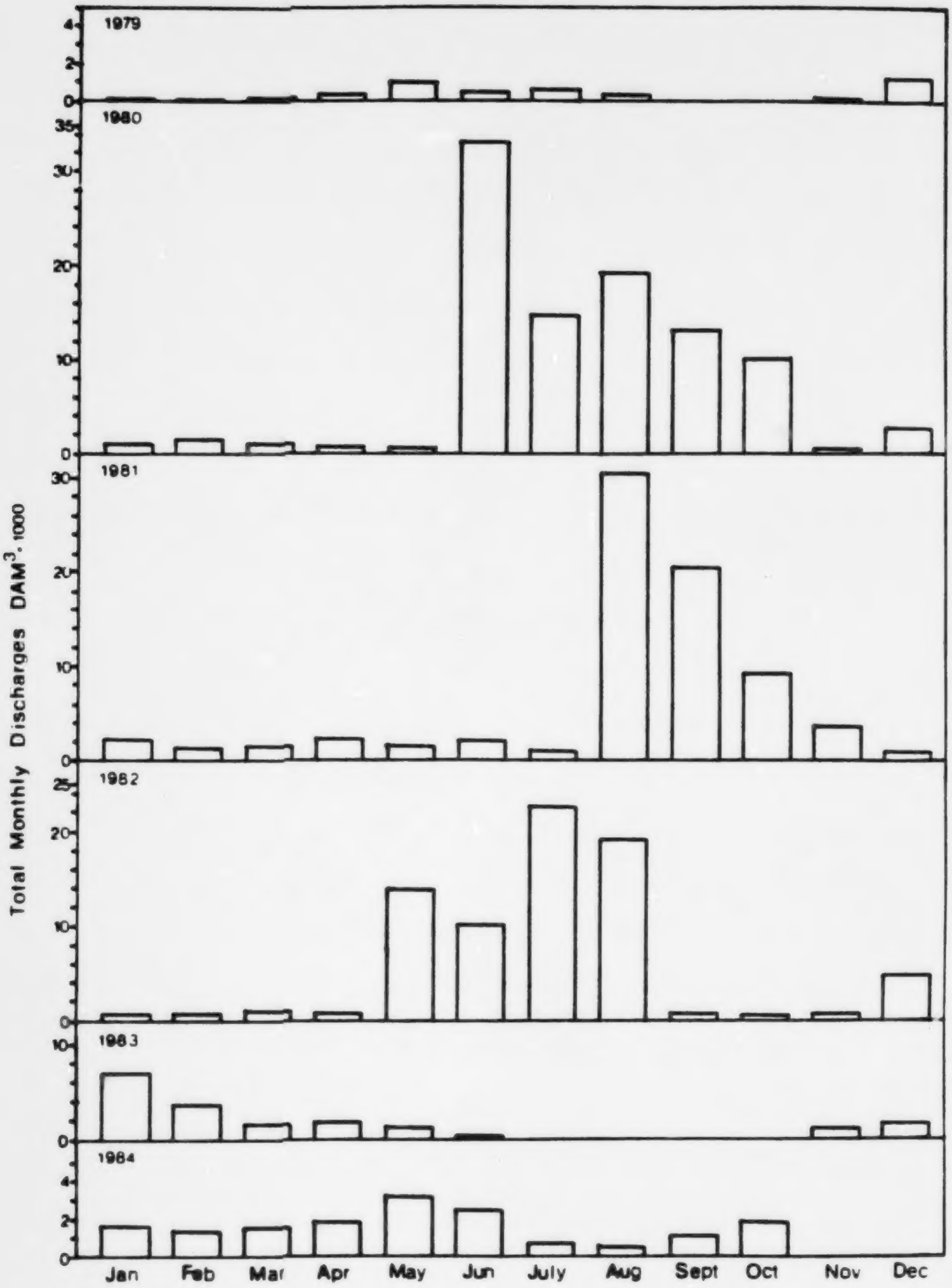

Fig. 11. Total monthly discharges from the Saskatchewan River (Old Channel) to the Cumberland Marshes via the Dragline Channel and Cut Beaver Lake for the years, 1979 - 1984.

METHODS

Migration of spawning run fishes through the Bracken Dam fish ladder into the Saskeram Marshes in 1983 and 1984 was monitored in a manner similar to that described by Leroux (1982). A trap (Fig. 12) consisting of a 1.4 metre square box constructed of 2" X 4"'s with a funnelled 15 cm wide slot entrance, was designed to fit to the upstream exit of the fish ladder. The trap was enclosed on all sides, except the top, with 9 mm mesh Vexar plastic netting. When the trap was fishing, the top was normally covered with a rubberized canvas to prevent the trapped fish, especially carp, from jumping out. The trap was suspended from a steel pole mounted on top of the dam and could be raised and lowered by means of a double pulley and rope. A wooden platform was suspended beside the trap to facilitate dipnetting and tagging the fish.

The fish ladder trap was put into place on May 8, 1983, but did not begin catching fish until May 15. In 1984, the trap was installed on April 18 and began catching on the following day. Depending on the numbers of fish moving upstream, the trap was lifted at various times and at least once each day. When fish movements were heavy, the trap was generally lifted in the morning and late afternoon or evening. Each fish was checked to detect any tags from previous years. Tag numbers of recaptured fish were recorded. All untagged fish were tagged with numbered FD-67 Floy anchor tags. Fish which had been tagged in 1981 and 1982 with unnumbered tags were generally tagged again with numbered tags. Upstream movements of fish through the fish ladder were monitored until August 23, 1983 and July 11, 1984.

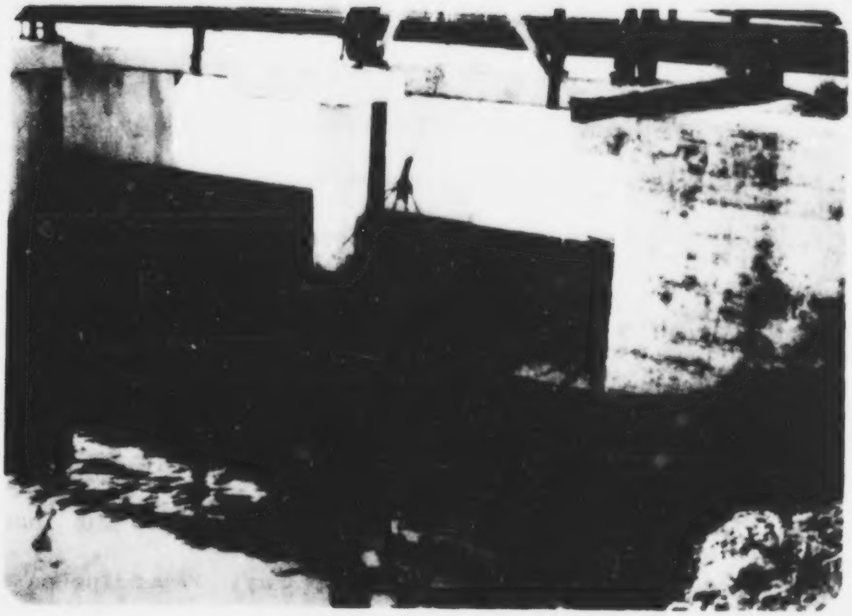

Fig. 12. Fish trap at exit of the Bracken Dam fish ladder.

Fork lengths, sex, maturity and spawning condition were noted on all fish tagged during the spawning runs at Bracken Dam in 1983 and 1984. Weights were recorded on all species in 1983 and walleye and carp in 1984. Ageing structures were taken from all species tagged except white suckers in 1983, and only walleyes and carp in 1984. A scale sample was taken above the lateral line on northern pike. Scale samples were taken below the lateral line on walleyes and carp; in addition a dorsal spine was removed from the walleyes and the pectoral spine from carp. Age composition of the 1984 spawning runs was estimated by taking a subsample of 20 each of pike and white sucker every day during the run. The complete pectoral fin was clipped from the white suckers and scales, the cleithrum and pelvic fin were taken from the pike for ageing. This subsample was also used for statistics on fork length, weight, sex, maturity and gonad condition. All ageing structures were taken from the fish's left side. The structures were numbered and dried for subsequent laboratory preparation and age determination. In the laboratory, the spines and fins were embedded in epoxy resin, thinly sectioned and mounted on glass microscope slides. Cleithra and scales required only some cleaning prior to ageing.

At the same time that fish movements into the Saskeram Marshes were being monitored in 1983, movements of fish in the lower Birch River were also examined. On May 16, one fyke net was set at a point called Pyott's Crossing (Fig. 3), approximately 5 km upstream of Bracken Dam. This area was shallow enough to permit the setting of fyke nets near the streambanks. The net was set near the south bank and was oriented to capture upstream moving fish. A lead was set across about three quarters of the stream width. A downstream trap net was set on the north bank on June 4 and leads (2.54 cm bar measure) were strung between the two nets and to each streambank to prevent fish from bypassing the nets, These nets were routinely inspected. All fish caught were again checked for tags. Any untagged fish were measured, weighed and tagged. Fish were released either upstream or downstream of the barrier, in accordance with the direction of observed movement. The Pyott's Crossing barrier was in operation from May 16 - August 6, 1983. A similar barrier was also operated in the lower Birch River immediately downstream of the outlet of Saskeram Lake. This barrier was in place from June 17 - September 17, 1983.

At the same time that the Pyott's Crossing barrier was in place in 1983, two gill nets (7.6 cm and 10.8 cm mesh nets, each 22.8 m long) were set at a point about 8 km upstream of Bracken Dam and also at the outlet of Saskeram Lake. The purpose of this netting was to further document movements of fish in the Birch River and to determine any outmigration of fish that may have overwintered in the Saskeram Marshes. These catch data, along with other information, were also employed to determine population estimates of adult fish. The Schumacher-Eschmeyer multiple mark- recapture method (Ricker 1975) was applied to derive estimates of population sizes of adult pike and white sucker in the lower Birch River system.

Some gill netting was also conducted at several locations in the Saskeram Marshes in an attempt to determine the rate of dispersion of tagged fish through the area. A description of this netting is as follows. A 22.9 m(25yd) section of 7.6 cm (3 in) mesh gill net was set below each of the following control structures - Birch Lake, Lake Six, and Elm Creek. Three more overnight sets on May 25, June 20 and July 27, 1983 were made at each of the following sites; above the Elm Creek and Lake Six control structures and in the Birch Lake area (Fig. 3). One set was made in Saskeram Lake proper on June 20. Visual observations on the species and numbers of fish in these areas were also recorded.

Several gillnetting trips were made to the upper Birch River system in the vicinity of Cumberland Dam. On May 23, 22.8 m nets of 7.6 cm and 10.8 cm mesh set upstream of Cumberland Dam, downstream of Cumberland Dam and about 2 km upstream from Birch Lake. The two sets downstream of the dam were made to see if fish tagged at Bracken Dam were moving into the area and the set above the dam was made to record the numbers and species of fish present. Between June 19 and 22, twelve lifts of 45.6 m of gillnet (22.8 m each of 7.6 cm and 10.8 cm) were made in the Cumberland Dam area. A number of pike was tagged downstream of the dam to get some idea of their movements in the system. The netting above the dam was carried out simply to see what species were present. Another trip was made to the Cumberland Dam area on August 15 and 16. Four 22.8 m sets were made of 7.6 cm, 1 - 22.8 m set of 10.8 cm were made in the Upper Birch below Cumberland Dam to see if tagged fish were present in the area. Two floating sets of 3.8 cm gillnetting were also made above the dam to get an indication of the number and size of underyearling pike present in the system.

Arrangements were made with L. Sullivan, a Conservation Officer in Cumberland House to set gillnets in the vicinity of Beaton Lake in the Cumberland Marshes system. Three 22.8 m nets (3.8 cm, 7.6 cm and 10.8 cm) were set on October 23 and lifted October 24. The netting was conducted to see what fish were in the system and what to expect in terms of immigration to the Saskeram Marshes system from upstream areas and the significance of this recruitment to winterkills in the Cumberland Dam area.

Shortly after the spring spawning run of fishes into the Saskeram Marshes was completed (about 10 - 15 days), three drift nets were set just upstream of Bracken Dam on May 30, 1983 and May 27, 1984. The drift nets were set just below the surface, and at depths of 0.5 and 1.0 m. The nets were the same as those used by Gaboury (1985) for capturing drifting walleye larvae in the Valley River. The purpose of this effort was to capture any larval fishes or fish eggs that may have been passively carried by flows out of the Saskeram Marshes. The drift nets were lifted and emptied once daily. They were removed on July 29, 1983 and July 11, 1984, when it was suspected that the larval drift period for spring spawning fishes was completed.

Small mesh fyke nets and/or a Beamish trap net (Beamish 1972) were also set at various locations in both the Birch River and marshy areas which were easily accessible by outboard motorboat. The intent of this sampling was to obtain some information on the degree of reproductive success by pike, walleyes and white suckers in the Saskeram Marshes.

The monitoring of fish leaving the Saskeram Marshes was started on May 26, 1983 and June 24, 1984. This monitoring was done, in part, using a spillway trap designed by Leroux (1982) which could be fitted to the stoplogs at Bracken Dam. The trap consisted of a metal framed structure enclosed on all sides, except the top, with 1.90 cm mesh flat steel screen (Fig. 13). One end of the trap was attached to and held in place by a bracket fitted to the downstream side of the stoplogs in one of the dam bays. The other end of the trap was suspended by two 0.65 cm wire cables attached to safety railings on the dam. A section of the stoplog the width of the trap was removed so that all water would flow through the trap. The bottom of the trap was partially inclined so that fish and any debris entering the trap would be moved to the back of the trap. Part of the sides and bottom of the trap were enclosed with plywood sheets to retain some water so that most fish could survive in the trap. To empty the trap of fish and clean out the accumulated debris, waterflow through the trap was stopped by placing a thin plywood board in front of the stoplog opening. The frequency with which the trap was checked and emptied depended upon the number of fish caught and the amount of debris. In 1984, a trash boom was placed across the Birch River just upstream of Bracken Dam; this substantially reduced the debris problem. In 1984, an additional spillway trap was placed on Bracken Dam on July 7; this trap was in the bay next to the fish ladder (Fig. 14). The spillway traps were checked daily. In 1983, the trap was operated until November 24 when icing conditions curtailed further operation. Spillway traps were operated until November 20, 1984, when it became obvious that fish movements out of the Saskeram Marshes had ceased. It should be noted that in 1983, several bays of Bracken Dam were partially opened during the summer (May 15-August 13) to allow water from the Cumberland Marshes to pass through the Saskeram Marshes. To reduce the possibility of downstream moving fishes being able to bypass the spillway

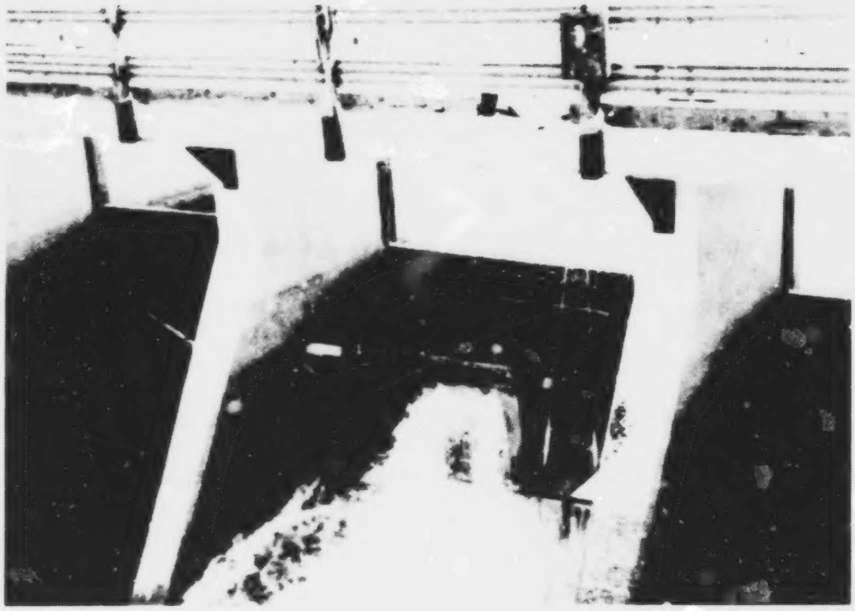

Fig. 13. Spillway trap used to monitor the outflow of large fish from the Saskeram Marshes at Bracken Dam.

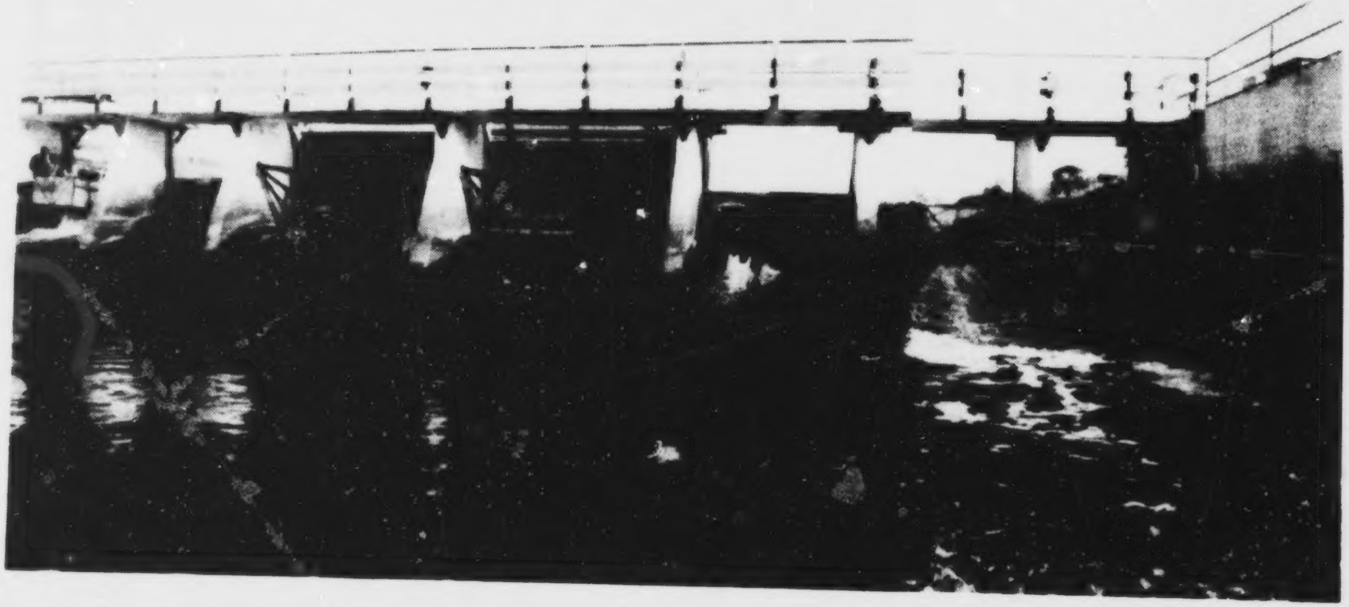

Fig. 14. Downstream view of Bracken Dam in September 1984, showing the placement of the traps in bays 2 and 7.

trap, a heavy net (2.54 cm mesh) was strung just above the dam so that fish moving along or near the north bank would be diverted into the spillway trap near the south bank. This diversion seemed to function relatively well, except it gilled large numbers of small pike and required frequent cleaning. Less spilling at Bracken Dam was required in 1984 and therefore most water passed through either the fish ladder or the spillway traps.

The Bracken Dam fish ladder was also utilized to monitor the emigration of fish from the Saskeram Marshes. The fish ladder was converted into a downstream trap by screening off the first compartment below the fish ladder exit (Fig. 15). The fish ladder could be almost completely dewatered by shutting off the exit. This allowed personnel to enter the fish ladder compartment and remove the fish with dipnets. On several occasions in 1983, difficulty was experienced in holding the fish ladder screen intact. This resulted from large numbers of small pike being impinged by the current and causing the plastic screening to give way. A similar problem was experienced in 1984 when extremely large numbers of brook stickleback plugged the screen. These difficulties were even experienced when larger wire mesh was used to replace the plastic screen. On these occasions, an unknown number of fish passed down through the fish ladder.

All fish species, except forage species such as sticklebacks and minnows, caught in the spillway and fish ladder traps were counted. Limited observations on the abundance of forage fish caught were made in 1984. In counting the pike, a distinction was made between juvenile and adult fish. Juvenile pike were primarily young-of-the-year and occasionally yearling pike and were readily identified on the basis of size relative to the other pike caught. In the case of white suckers, the numbers of young-of-the-year fish were recorded. All live fish were released downstream of Bracken Dam. All fish in both years were checked for tags. In 1984, live adult pike and white suckers were measured for fork length and, if untagged, were tagged. During both years, periodic samples of small pike and some white suckers were taken for detailed measurements.

Throughout each field study period, a continuous record of water temperature was taken at Bracken Dam using a Ryan thermograph. Daily water levels were recorded from staff guages on the upstream and downstream abutments of the dam. Dissolved oxygen readings, using the Winkler method, were taken regularly from the Birch River immediately above Bracken Dam. Dissolved oxygen was also measured at a couple of other locations on the Birch River throughout the monitoring period (Appendix XXXIa & b).

Dissolved oxygen was monitored at 16 locations in the Saskeram Marshes and along the Birch River on January 17 and 18, 1984 and at 11 sites on February 21 and 23, 1984 (Fig. 16). Ice thickness and water depth at each testing site were recorded. Special note was also made of any numbers of dead fish in the vicinity of sampling locations. During the 1983-84 winter season, gillnets were also set for 2 days in the Birch River immediately below Cumberland Dam and at Pyott's Crossing (Fig. 3) on January 17. The purpose of the netting was to determine winter survival of fish. The net set at Pyott's Crossing froze to the bottom of the ice and could not be lifted until the following spring (April, 1984).

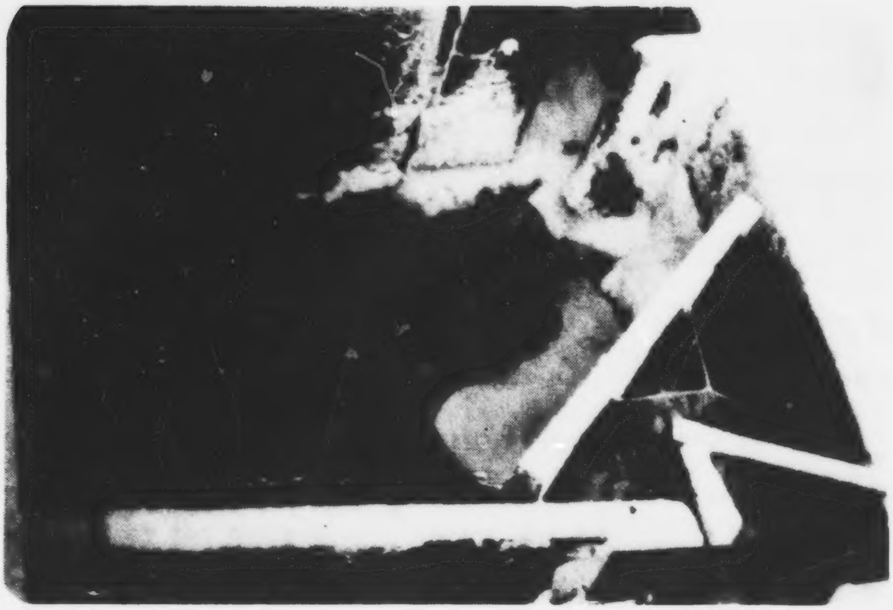

Fig. 15. The fish ladder trap used to catch downstream moving fishes at Bracken Dam.

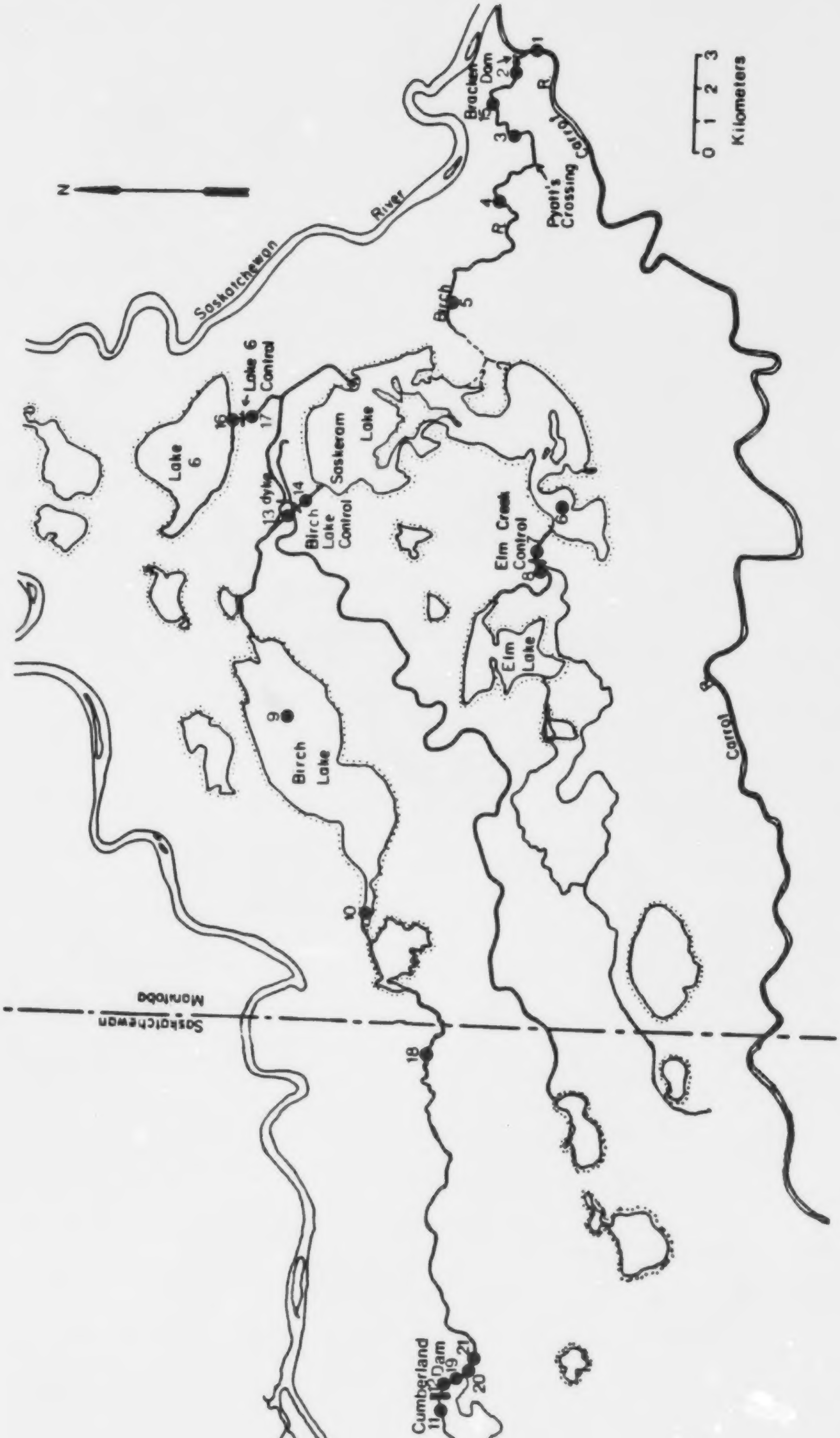
N
Saskatchewan River
Bracken Dam
1
2
3
4
5
R
Pyott's Crossing
Carrot R
Birch R
Lake 6 Control
16
17
Lake 6
13 dyke
14
Birch Lake Control
Saskeram Lake
Elm Creek Control
6
7
8
Elm Lake
9
Birch Lake
10
Saskatchewan
Manitoba
18
Cumberland Dam
11
12
19
20
21
Carrot R
0 1 2 3
Kilometers

Fig. 16. A partial map of the Saskeram and Cumberland marshes showing the locations of the winter oxygen testing stations.

RESULTS

FISH MOVEMENTS

Information on catches, as well as tag/recapture results were employed to interpret the movement patterns of large fish in the Saskeram Marshes. Special emphasis is given to the movement of fish into and out of the Saskeram Marshes via Bracken Dam. This information formed the basis on which estimates were made of the net productivity of fish from the marshes. Movements of fish throughout the Saskatchewan River Delta upon leaving the Saskeram Marshes are considered. Some attempts are also made to determine the distribution of fish through the Saskeram Marshes and the degree to which they home to the area to spawn.

Upstream Fish Movements into the Saskeram Marshes

The movement of spring spawning fishes through Bracken Dam and into the Saskeram Marshes varied between 1983 and 1984, but appeared to be strongly correlated with water temperature. The upstream movement of pike, walleyes and white suckers, as indicated by catches in the Bracken Dam fish ladder trap, began May 15 in 1983 (Fig. 17). Water temperatures at Bracken Dam at this time were around 3°C, but rose to a range of 8-10°C several days later (Appendices Ia & IIa). Pike were observed immediately below the dam prior to moving upstream, but appeared indisposed to moving into the fish ladder. This delay may have been due to the presence of foul-smelling water coming out of the Saskeram Marshes, and lower flows over Bracken Dam as well as to the lower water temperatures.

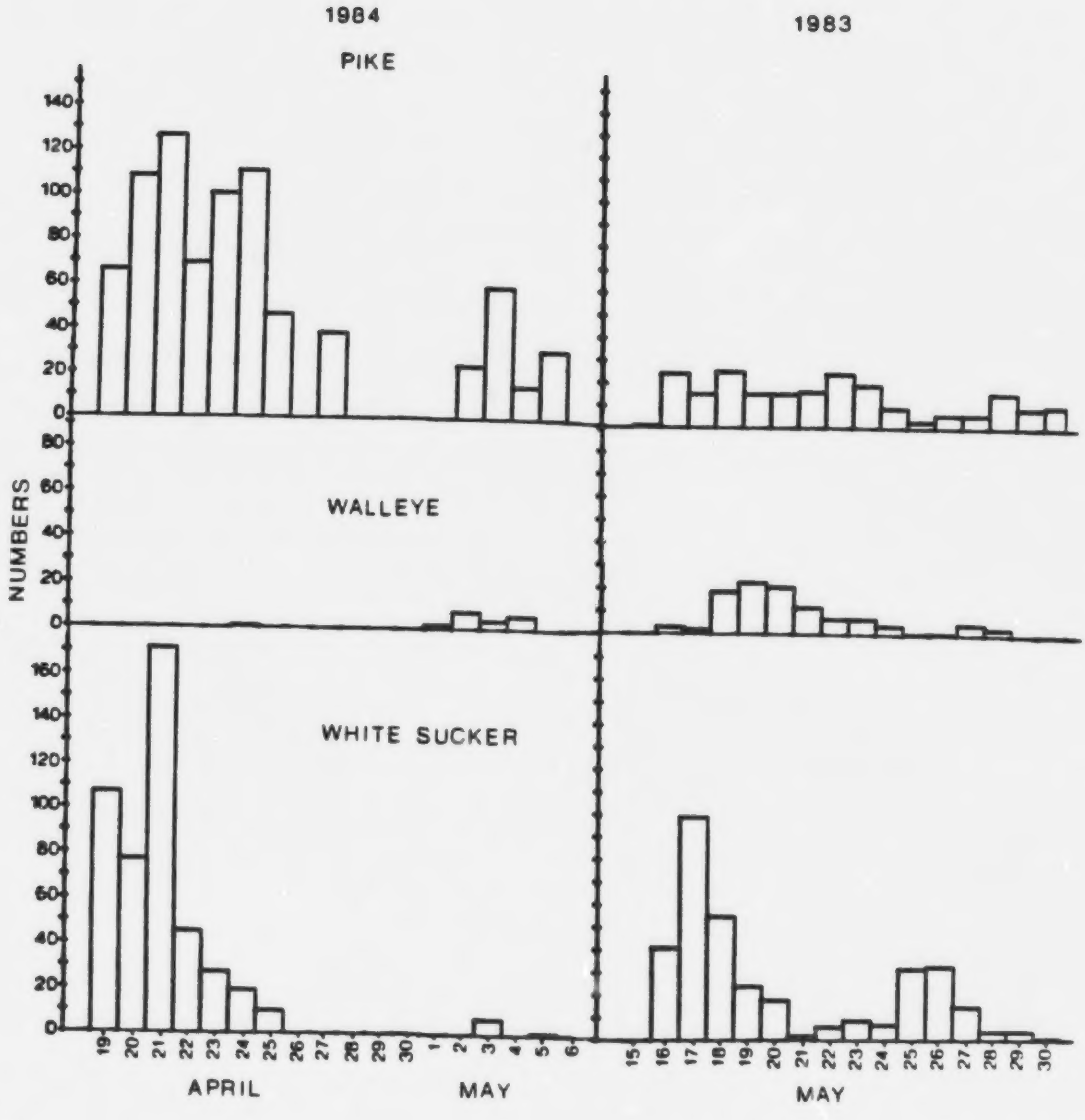

Fig. 17. Daily upstream movements of northern pike, walleyes and white suckers through the Bracken Dam fish ladder in April and May, 1983 and 1984.

In 1984, pike and white suckers began moving into the the Saskeram Marshes by April 19. Water temperature at this time was 8.5°C (Appendices Ib & IIIa). During the early part of this run, pike were actively jumping below the dam. Pike were frequently observed clearing the water surface by about 1.0 m. Since the difference in water levels at Bracken Dam was 1.06 m at this time (Fig. 8), an occasional pike was observed jumping over the dam. Although walleyes were not caught in any numbers in the fish ladder trap until May 1 (Fig. 17), they did appear in significant numbers in the Birch River below Bracken Dam. This appearance was coincident with the spawning runs of pike and suckers. Large numbers of anglers, as many as 15 to 20 on some days, were observed making good catches of walleyes in the area. These walleyes were in or near spawning condition, but it is not known whether they were spawning on the rock rubble immediately below Bracken Dam. No obvious factors could be identified to explain why the walleyes did not move into the Saskeram Marshes in greater numbers. Although late summer and autumn water levels in the Birch River below Bracken Dam were exceptionally low in 1984, head differences and flows at Bracken Dam during the spawning run periods in 1983 and 1984 were not substantially dissimilar. Bracken Dam in 1984 did not appear to be any more of a barrier to the upstream movement of walleyes than it did in 1983. Nevertheless, approximately four times as many walleyes were captured at the Bracken Dam fish ladder in 1983 as compared to 1984 (Fig. 17).

Water temperatures continued to rise following breakup in 1983 and reached 15°C by June 1. This uniform increase in water temperatures is associated with the absence of any pronounced peak in either the pike or walleye spawning runs. A well defined peak, however, was observed in the sucker run on May 17; water temperature then was 8.5°C. This was then followed by a smaller peak on May 25-26 when the water temperature was around 11°C.

In 1984, a severe snowstorm and cold weather during the last week of April resulted in a drastic drop in water temperatures. Temperatures declined from 12.2°C on April 25 to 2.0°C three days later and did not reach 12°C again until May 15. The sharp drop in water temperatures affected the movement of pike and suckers into the Saskeram Marshes. From April 23 - May 1, when temperatures were less than 4°C, no fish were caught at Bracken Dam. Pike did not reappear at the dam until May 2, when the water temperature reached 5.5°C. Most (~80%) of 163 pike caught going upstream at Bracken Dam in May 1984 were caught during the first week, suggesting a continuation of the earlier spawning run. The spawning run of white suckers into Saskeram peaked on April 21 and then rapidly declined even before the water temperatures dropped. The run did not reappear after the cold snap had passed.

Fish continued to move up the Bracken Dam fish ladder following the spring spawning runs. Small numbers (1-3) of pike occurred sporadically throughout the month of June, 1983 (Appendix IIb). During the last part of July, 1983, daily catches of pike at Bracken Dam increased appreciably (Appendix IIc). This may have been in response to increased discharges from the Cumberland Marshes and routed through the Saskeram Marshes. The movement into the Saskeram Marshes of small quantities of suckers continued through June, but declined sharply in

July (Appendices II b & c). Only 2 pike were caught during the period August 1-23, 1983, after which the fish ladder was converted into a downstream trap. Post - spawning run surveillance of upstream fish movement in 1984 exhibited trends closely similar to the 1983 results (Appendices III b & c). However, discharges at Bracken Dam in 1984 were not as great as in 1983 and by mid-summer the river level below the dam had dropped to a point where much of the stream bottom was exposed (Fig. 9). This limited the number of post-spawning upstream migrants. During the period July 1-10, 1984, only 17 pike were caught up to July 6. No fish was caught in the succeeding 4 days, so monitoring of upstream movements was stopped.

Carp were observed moving upstream through the Bracken Dam fish ladder on June 1, 1983 and May 28, 1984 (Fig. 18). These movements represented spawning runs since all specimens were sexually mature and in spawning condition. The carp did not appear to begin moving upstream until water temperatures had reached at least 14°C. The spawning run in 1983 peaked when temperatures had reached 17°C and lasted for 5 to 7 days. The 1983 run (68 fish) was also three times larger than the 1984 run (22). The occasional carp was caught moving upstream well after the spawning run had passed.

The upstream movements of fish at Bracken Dam in 1983 differed in several ways from the movements observed in 1984. Nearly twice as many fish moved past Bracken Dam in 1984 as compared to 1983. Fewer pike than suckers moved upstream in 1983; the opposite was true in 1984 (Table 2). More walleyes and carp moved upstream in 1983 than in 1984. Despite these differences, there were some marked similarities between

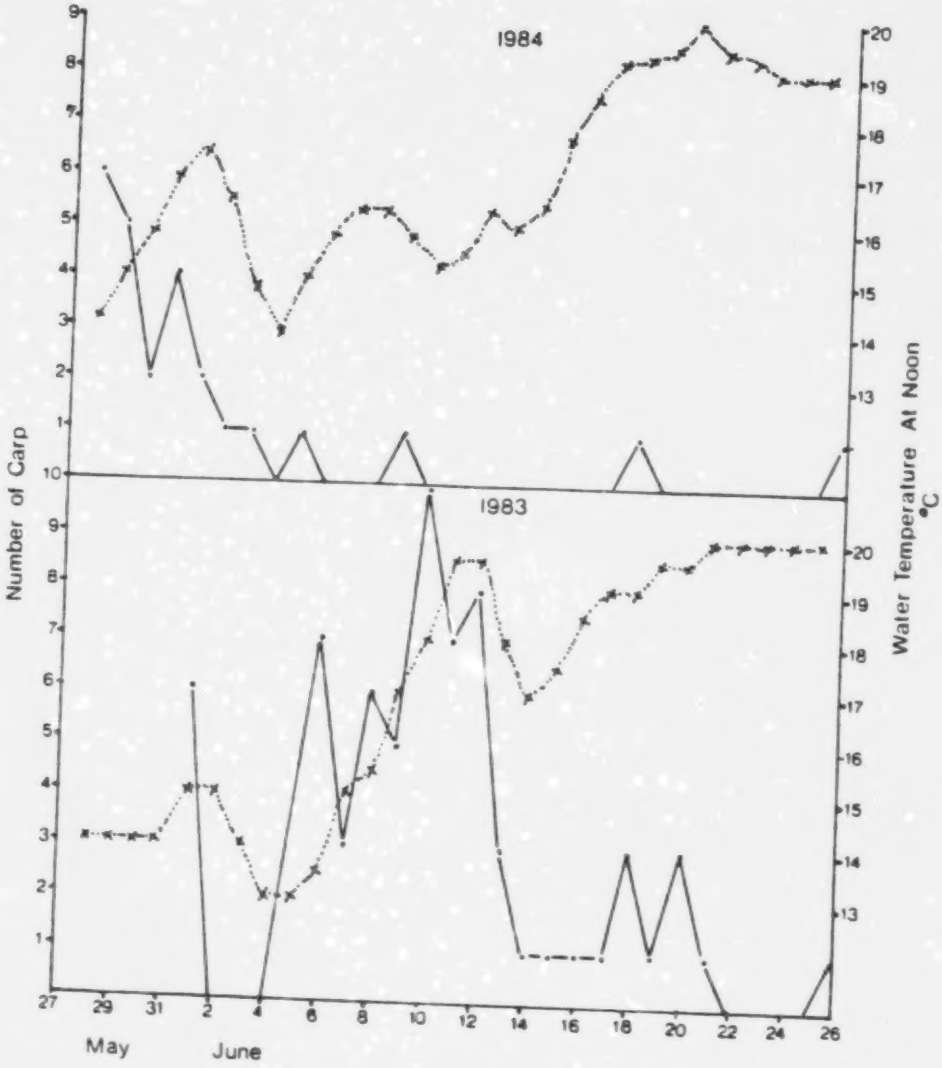

Fig. 18. Daily catches of carp (solid lines) in the Bracken Dam fish ladder trap during May and June, 1983 and 1984, and their relationship to water temperatures (dotted lines).

Table 2. A monthly summary of upstream fish movements through the Bracken Dam fish ladder in 1983 and 1984. Percentages of catches of each species per month are given in parentheses.

Month	Species				Total
	Northern pike	White sucker	Walleye	Carp	
1983					
May 15	213 (67)	350 (90)	108 (100)		671 (76)
June	15 (5)	28 (7)		68 (99)	111 (13)
July 31	90 (28)	10 (3)		1 (1)	101 (11)
Total	318	388	108	68	883
1984					
April 19	663 (72)	456 (86)	1 (4)		1120 (74)
May	163 (18)	36 (7)	26 (96)	17 (68)	242 (16)
June	82 (9)	34 (6)		8 (32)	124 (8)
July 10	17 (1)	3 (<1)			20 (1)
Total	925	529	27	25	1506

the overall upstream movements in 1983 and 1984. Most notable were the observations that approximately 70 per cent of the pike and about 90 per cent of the white suckers moved upstream in the first two weeks in each year's study. Considering all species combined, about 75 per cent of the fish moved into the Saskeram Marshes in the two weeks after the area became free of ice and was recharged with oxygen. Based on the two years of results, these events appear predictable, but may vary slightly from year to year depending on prevailing weather conditions.

Some trends were observed in the catch data which suggested a diurnal periodicity in the upstream movement of fish at Bracken Dam. Although the catches could not be equated precisely to the hours the movements occurred, trap catches recorded during the AM may be considered to include most of the fish that had moved upstream during the night or early morning (up to 9:00 AM). PM catches represented only fish which had moved upstream before dark. In 1984, more pike and suckers moved upstream on the April spawning run during daylight hours (Table 3). A similar tendency was again observed for these species, as well as walleyes, in May, 1983. Post-spawning run catches were too small and sporadic to show any consistent trends.

Fish Movements Within the Saskeram Marshes

The movements of fish within the Saskeram Marshes were described by examining the results of tagging and recapture experiments in both years of the study. The interpretation of fish movements in the marshes also relied, to some extent, on results of tag releases in previous years. Particular emphasis was given to the 1983 mark-recapture results. In 1983, 720 fish were tagged and released upstream at Bracken

Table 3. Numbers of fish moving upstream through the Bracken Dam fish ladder during the approximate hours of darkness (AM) and daylight (PM) during each month in 1983 and 1984.

		Species				
Month		Northern pike	White sucker	Walleye	Carp	Total
1983						
May	AM	106	164	46		316
	PM	107	186	62		355
June	AM	8	17		25	50
	PM	7	11		41	59
July	AM	21	0		1	22
	PM	69	13		0	82
1984						
April	AM	268	106	1		375
	PM	396	350	0		746
May	AM	101	24	23	17	165
	PM	62	10	3	0	75
June	AM	76	33		8	117
	PM	0	0		0	0
July	AM	14	3			17
	PM	3	0			3

Dam (Appendix IVa). Efforts to recapture these marked fish upstream at Pyott's Crossing, in the vicinity of the Saskeram Lake outlet, and at several intervening sites revealed a high proportion of untagged pike and suckers. The greatest numbers of unmarked fish were caught at Pyott's Crossing and the outlet of Saskeram Lake; 1024 and 510, respectively. As will be shown later, most of these fish (>70%) were caught while they were apparently moving downstream in late June and early July.

In 1984, a total of 1150 fish, mostly pike and white suckers, were tagged at Bracken Dam and released into the Saskeram Marshes (Appendix IVb). No efforts were made to follow upstream movements in the lower Birch River. Several attempts, however, were made throughout the summer to recapture tagged fish at Cumberland Dam to ascertain whether the fish would traverse the entire length of the Saskeram Marshes. Fourteen pike were also tagged and released in the Birch River immediately below Cumberland Dam.

The interpretation of fish movements, especially those of pike, within the Saskeram Marshes in 1983 was complicated by several factors. Firstly, as noted previously, the entire width of the Birch River at Pyott's Crossing was not closed off completely during the early spawning runs into the marshes. A good proportion of the fish released above Bracken Dam were therefore likely able to evade capture on their upstream migration into the marshes. Secondly, traps to recapture fish at the outlet of Saskeram Lake were not set in place until well after the peak in upstream movements at Bracken Dam. Thirdly, the barriers placed in the Birch River at Pyott's Crossing and the outlet to Saskeram Lake were not totally effective. The pattern of tag recoveries in some instances indicated that fish were able to by-pass the nets. Fourth, equal efforts were not made at various locations to recapture tagged fish. For example, trapping at Pyott's Crossing was discontinued about a month earlier (Aug. 6) than at the Saskeram Lake outlet (Sept. 17). Finally, the influx of a large number of unmarked fish in June and July in the Pyott's Crossing area made it difficult to reach conclusions respecting the orientation of fish movements during the mid-summer period. The following described patterns of fish movements therefore may be in part a reflection of the distribution and intensity of efforts to recapture fish in the marshes.

Northern pike - Eighty-two percent of the 1644 pike tagged and released into the Saskeram Marshes in 1983 were fish that were already in the marshes or had somehow bypassed Bracken Dam unnoticed (Fig. 19). Almost 75 per cent of the untagged pike were captured in the downstream traps and mainly at Pyott's Crossing. Only 21 per cent of the fish were caught in traps set to intercept upstream moving fish. Approximately half (52%) of the upstream moving pike were caught near the outlet of Saskeram Lake. The majority of untagged pike caught above Bracken Dam were taken during the last two weeks of June and first week of July.

Two hundred and six adult or spawning-run pike were tagged and released at Bracken Dam during the period May 15 - 31, 1983. The timing and pattern of movements by these fish could be well documented since 52 per cent were recaptured within the first year. Although the monitoring of these movements was deficient in some respects, it is noteworthy that most pike in the upstream trap at Pyott's Crossing were taken in May (Table 4). The majority of upstream recaptures at Pyott's Crossing were

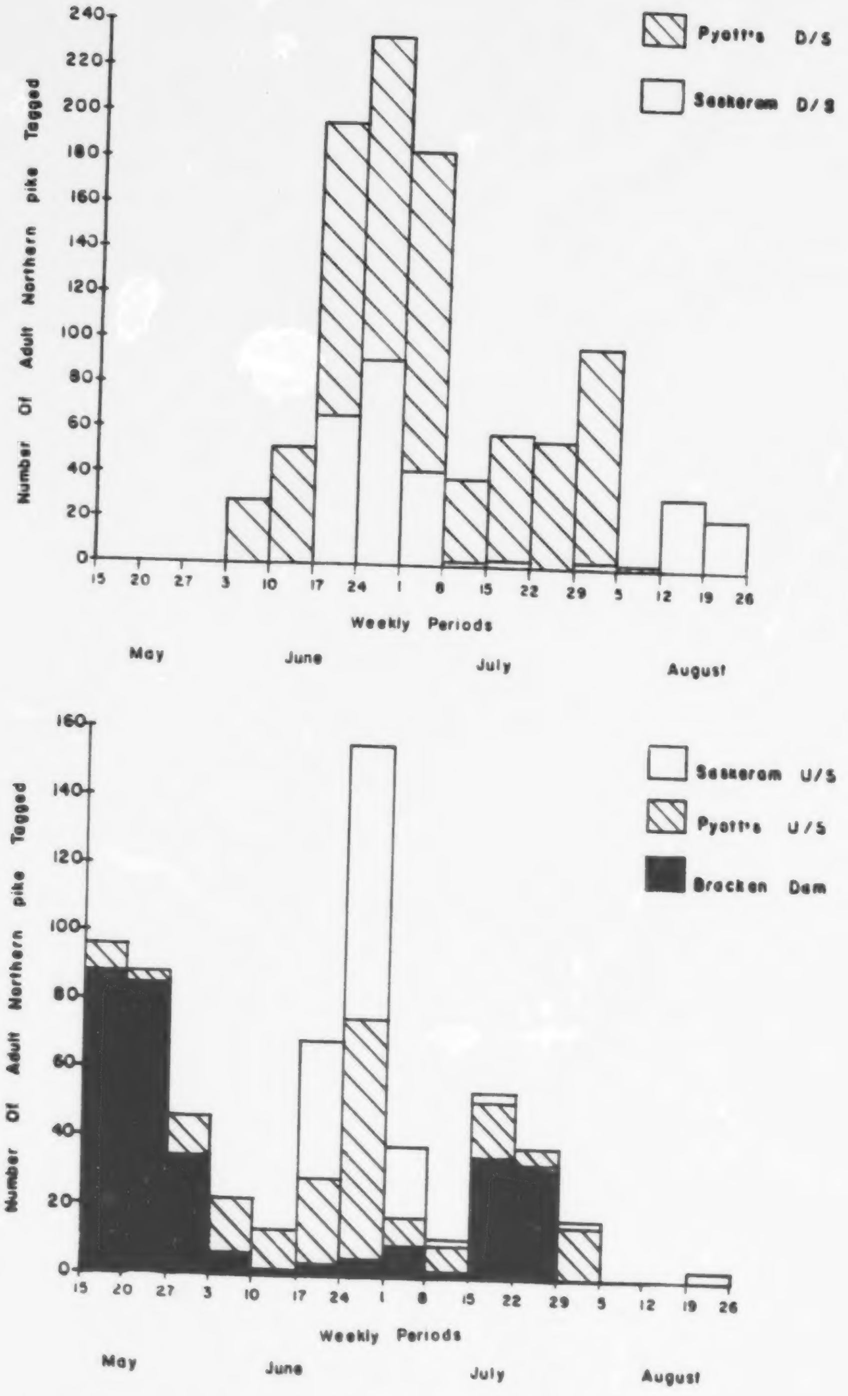

Fig. 19. Numbers of northern pike tagged and released at the Bracken Dam, Pyott's Crossing and Saskeram Lake traps during weekly periods from May through August, 1983.

Table 4. Spatial and temporal distribution at recaptures of pike tagged at Bracken Dam during the May 15 - 31, 1983 spawning run into the Saskeram Marshes.

	Recapture Location						
	1	2	3	4	5	6	7
No. of Recaptures*	6	13	6	21	17	47	33
Range in Dates of Recapture	June 8 June 18	May 20 July 29	June 24 July 20	May 20 July 16	June 18 Aug. 11	June 10 Aug. 5	June 13 Oct. 15
Month of Most Recaptures	June	May	June	June	June	June	June

1. ∿ 2 km upstream of Bracken Dam.
2. Pyott's Crossing - upstream trap.
3. Saskeram Lake - upstream trap.
4. Saskeram Lake
5. Saskeram Lake - downstream trap.
6. Pyott's Crossing - downstream trap.
7. Bracken Dam - downstream traps.

* Includes double recaptures.

also within 5 days of tagging; very few were caught after 20 days (Fig. 20). These results suggest the fish had a strong upstream orientation at this time. It is not known how soon these pike moved further into the Saskeram Marshes, since the traps at the Saskeram entrance were not placed until June 17. It is believed that most of the spawning-run pike, passed quickly through the lower Birch River and dispersed throughout Saskeram Lake. This conjecture is supported by observations on the distributions of several tagged pike recaptures. For example, two pike released at Bracken Dam on May 19 were recaptured 6 days later (May 26) at the Lake Six control structure. Another individual tagged at Bracken Dam on May 23 was netted 2 days later at the Elm Creek control.

The pike which moved into the Saskeram Marshes between May 15 - 31 did not appear to remain in the marshes long after spawning. Beginning June 10, significant numbers of these pike began appearing in the downstream traps and predominantly during the latter half of June. The largest proportion of these fish were caught in the Pyott's Crossing area (Table 5). The high number of recaptures in the downstream traps at Bracken Dam, especially in June, indicates many of the fish moved out of the marsh system within 30 - 40 days. This outward orientation is reflected in recapture pattern of some fish. For example, fish caught in the downstream trap at Pyott's were frequently caught in the spillway trap of Bracken Dam 1 - 2 days later. On the other hand, some pike tended to remain within the marsh system for longer periods of time. This loitering was suggested in some situations where tagged pike were first caught in a downstream trap at one site and later recaptured at another location upstream. In some instances it was obvious that the

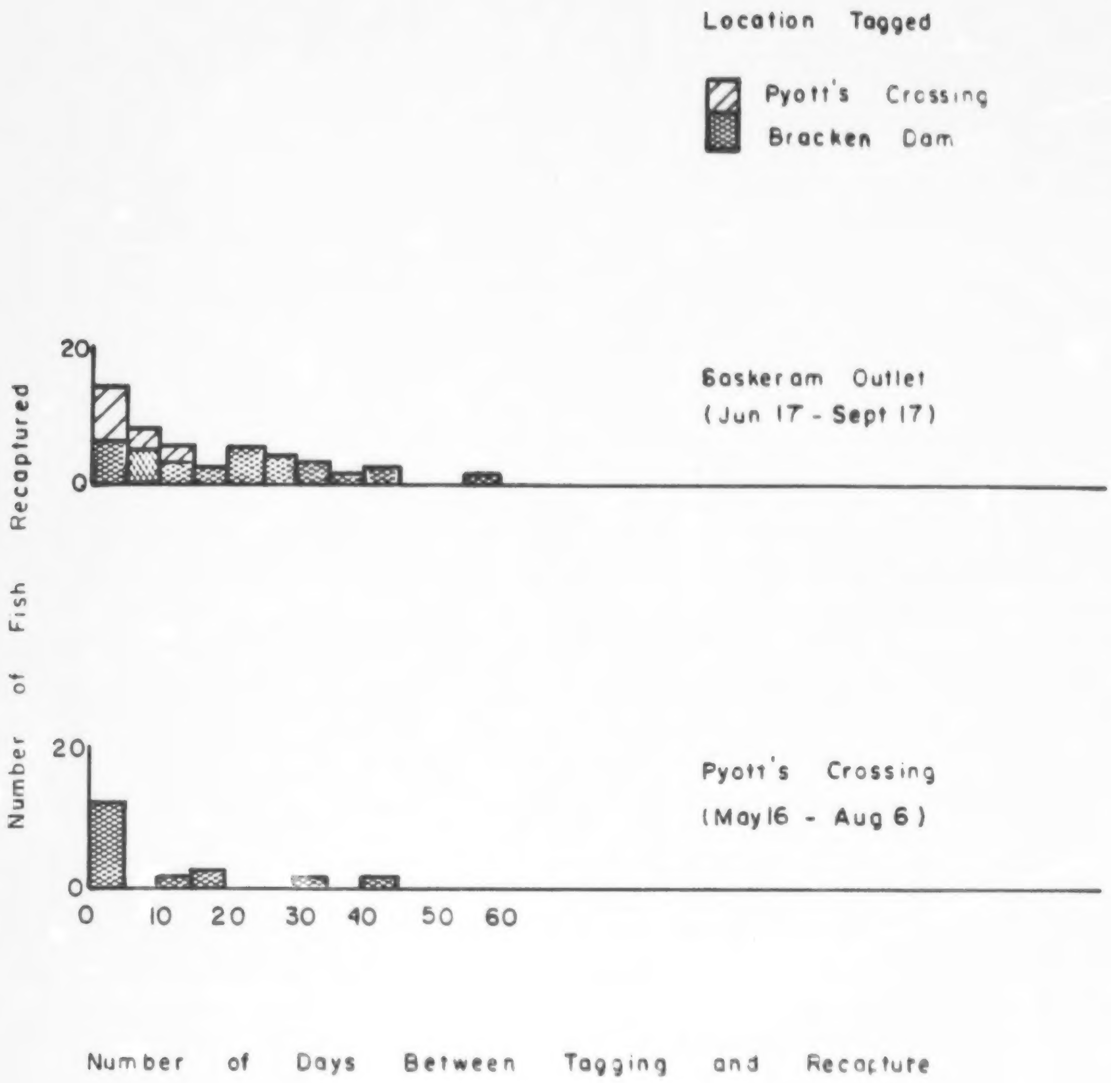

Fig. 20. Upstream net recaptures of northern pike tagged and released at Bracken Dam and Pyott's Crossing in 1983. Dates in parentheses are the times nets at those locations were in operation.

Table 5. Spatial and temporal distribution of recaptures of pike tagged in the lower Birch River at the Pyott's Crossing downstream trap during June, 1983.

	Recapture Location						
	1	2	3	4	5	6	7
No. of Recaptures*	14	6	4	2	31	10	53
Range in Dates of Recaptures	June 20 Aug. 20	June 9 July 1	June 20 Aug. 20	June 26 July 7	June 11 Aug. 4	June 11 Aug. 6	June 10 Oct. 16
Month of Most Recaptures	June	June	-	-	July	June	June

1. Saskeram Lake - upstream trap
2. Saskeram Lake
3. Saskeram Lake - downstream trap
4. Pyott's Crossing - upstream trap
5. Pyott's Crossing - downstream trap
6. 2 km upstream of Bracken Dam
7. Bracken Dam - downstream traps.

* Includes double recaptures.

fish had circumvented our temporary net barriers. The last of the spawning-run pike tagged at Bracken Dam was observed leaving the marsh system on October 15.

The unmarked pike which were encountered in the lower Birch River, mainly during late June - early July, exhibited distributional patterns similar to those of the spawning run fish. In general, those fish caught earlier in the summer in downstream traps appeared to be on an outwardly directed migration and moved out of the Saskeram Marshes quickly. For example, the majority of recaptures of pike tagged and released from the downstream traps at Pyott's Crossing and the Saskeram Lake outlet during June were caught almost immediately (i.e. in June) in downstream traps at Pyott's Crossing and Bracken Dam (Tables 5,6). Pike which were intercepted in downstream traps later in the summer (July) and in upstream traps during June seemed to linger within the lower Birch River area for a longer period of time. Most of the pike tagged from upstream traps in June were either caught within the lower Birch River during June or at Bracken Dam in October (Tables 7,8). Releases from downstream traps in July were generally recaptured during August (Table 9).

The temporal distribution of tagged pike recaptures in downstream traps in 1983 is shown in Fig. 21. This analysis confirms that most pike left the Saskeram Marshes within a month after spawning and that the bulk of the untagged pike encountered in the lower Birch River during June and July were moving out of the system. Some pike, however, did linger within the system. The exact proportion of the pike population that was involved is difficult to determine for two reasons. First, the downstream trap at Pyott's Crossing, which produced good

Table 6. Spatial and temporal distribution of recaptures of pike tagged in the lower Birch River near the outlet of Saskeram Lake (downstream trap) during June, 1983.

	Recapture Location			
	1	2	3	4
No. of Recaptures*	8	3	39	28
Range in Dates of Recaptures	June 26 July 14	June 30 Aug. 1	June 21 Aug. 5	June 21 Oct. 25
Month of Most Recaptures	July	-	June	June

1. Saskeram Lake - upstream trap
2. Saskeram Lake
3. Pyott's Crossing - downstream trap
4. Bracken Dam - downstream traps

* Includes double recaptures

Table 7. Spatial and temporal distribution of recaptures of pike tagged in the lower Birch River at Pyott's Crossing upstream trap during June, 1983.

	Recapture Location					
	1	2	3	4	5	6
No. of Recaptures*	5	3	3	15	1	2
Range in Dates of Recapture	June 25 July 28	June 13 July 1	July 18 Aug. 20	June 13 July 17	June 10	Aug. 29 Oct. 26
Month of Most Recaptures	June	June	Aug.	June	-	-

1. Saskeram Lake - upstream trap
2. Saskeram Lake
3. Saskeram Lake - downstream trap
4. Pyott's Crossing - downstream trap
5. 2 km upstream of Bracken Dam
6. Bracken Dam - downstream traps

* Includes double recaptures

Table 8. Spatial and temporal distribution of recaptures of pike tagged in the lower Birch river near the outlet of Saskeram Lake (upstream trap) during June, 1983.

	Recapture Location			
	1	2	3	4
No. of Recaptures*	3	4	27	13
Range of Dates of Recaptures	June 29 Aug. 8	June 25 Aug. 5	June 24 Aug. 6	June 29 Oct. 26
Month of Most Recaptures	June	June	June	Oct.

1. Saskeram Lake
2. Saskeram Lake - downstream trap
3. Pyott's Crossing - downstream trap
4. Bracken Dam - downstream traps

* Includes double recaptures

Table 9. Spatial and temporal distribution of recaptures of pike tagged in the lower Birch River at Pyott's Crossing downstream trap during July, 1983.

	Recapture Location				
	1	2	3	4	5
No. of Rcaptures*	2	1	3	18	23
Range in Dates of Recaptures	July 5 July 8	Aug. 11 -	July 13 Aug. 11	July 11 Aug. 8	July 3 Oct. 15
Month of Most Recaptures	July	-	July	Aug.	July & Aug.

1. Saskera Lake - upstream trap
2. Saskeram Lake - downstream trap
3. Pyott's Crossing - upstream trap
4. Pyott's Crossing - downstream trap
5. Bracken Dam - downstream trap

* Includes double recaptures

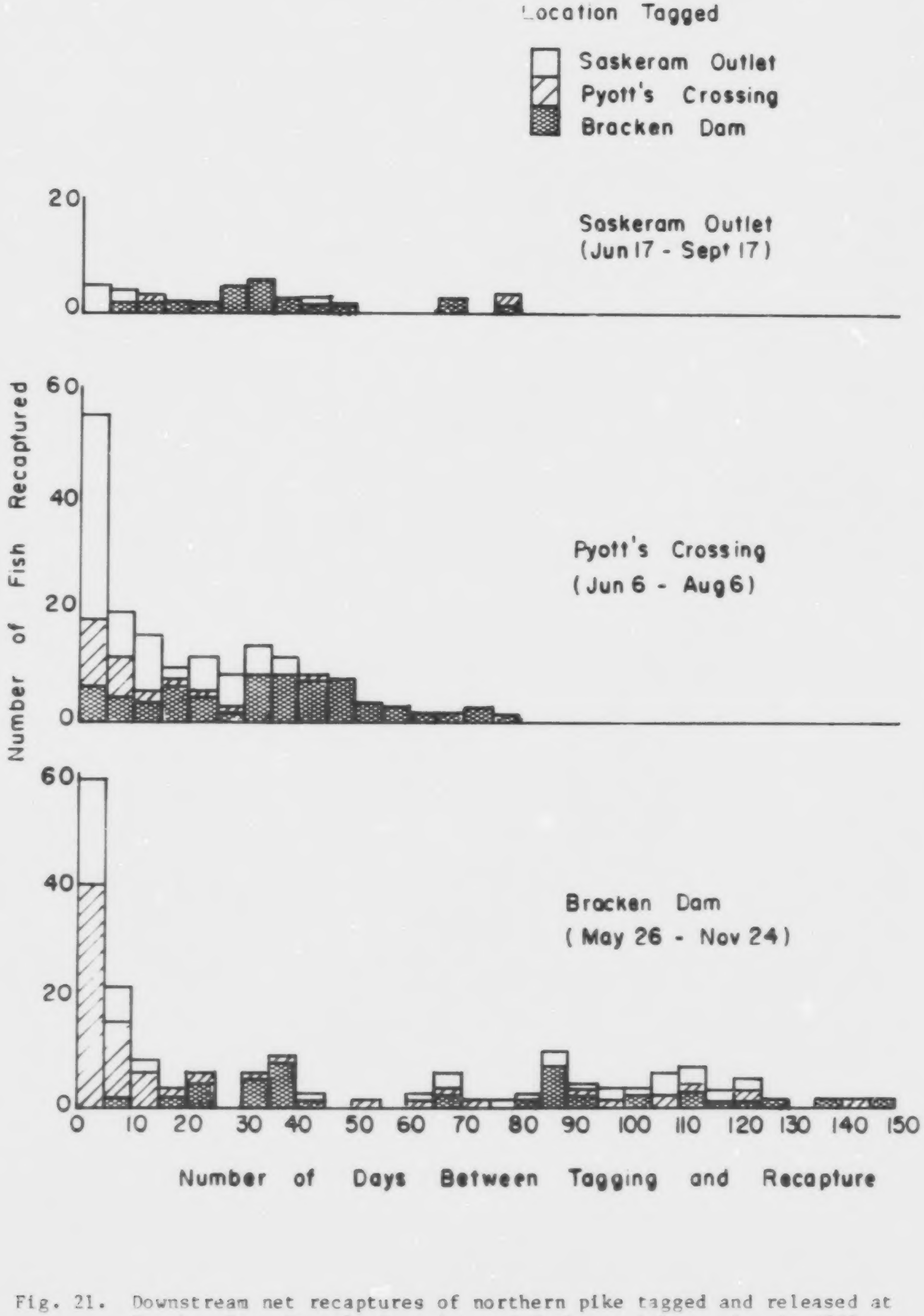

Fig. 21. Downstream net recaptures of northern pike tagged and released at Bracken Dam, Pyott's Crossing and Saskeram Lake outlet in 1983. Dates in parentheses are the times nets at those locations were in operation.

catches of pike, was removed early in August. Secondly, the entire outflow at Bracken Dam was not screened until August 13. We were therefore unable to maintain total surveillance on all tagged and untagged fish leaving the Saskeram Marshes.

Since little effort was made in 1984 to recapture pike upstream of Bracken Dam, movements within the Saskeram Marshes in that year cannot be described. Only one adult pike tagged and released at Bracken Dam on April 25 was recaptured just downstream of Cumberland Dam a month later, on May 24. This indicates that the pike will cross the entire system if conditions permit. The high proportion (36%) of recoveries at Bracken Dam of pike tagged near Cumberland Dam (Table 10) indicates the fish will also make the return journey.

It is not known whether in fact all of the pike which ran up into the Saskeram Marshes left or remained in the area over winter. Of the 721 adult pike which were tagged at Bracken Dam and released into the Saskeram Marshes between April 18 and July 10, 1984, only 115 (16%) were recaptured moving out in the first year. Most of these fish (92) left in July (50), August (14) and September (28). As will be noted later a large number of untagged pike was observed leaving the marshes in the autumn. Since there was some evidence of a certain amount of tag loss, there is the possibility that the numbers of returning, outward-bound pike may be underestimated.

White suckers - Almost equal numbers of white suckers were tagged and released at Bracken Dam and in the lower Birch River. Forty-eight per cent of the total number of suckers tagged (485) were marked and released within the Saskeram Marshes. Virtually all of the

Table 10. Recoveries of 14 adult pike tagged and released in the upper areas of the Saskeram Marshes between June 19 - 22, 1984.

Date Tagged	Tagging Location	Recapture Location	Recapture Date
June 20	Cumberland Dam (D/S)	Bracken Dam (D/S)	October 6/84
June 21	Birch Lake	" "	October 6/84
June 21	" "	" "	September 16/84
June 21	" "	" "	September 18/84
June 21	" "	" "	September 27/84

suckers intercepted moving upstream were caught at Bracken Dam; very few were caught at Pyott's Crossing and almost none at the Saskeram Lake outlet (Fig. 22). Most of the untagged suckers were caught in the downstream traps and about twice as many were caught at Pyott's Crossing than at the Saskeram Lake outlet (Fig. 22)

The majority (58%) of the 214 spawning-run suckers that entered the Saskeram Marshes at Bracken Dam from May 15 - 31 were recaptured in the first year. Although recoveries of spawning-run suckers in the upstream traps were low, their timing and distribution suggested a strong tendency for upstream movement (Fig. 23). Recoveries in the downstream traps indicated that unlike the pike, the white suckers exited the marsh very early (Fig. 24). With the exception of the occasional unmarked suckers, all of the white suckers in 1983 had left the Saskeram Marshes by the end of June.

None of the 380 white suckers tagged while moving upstream through the Bracken Dam fish ladder in 1984 was recovered in the Saskeram Marshes. Only 6 per cent of these suckers were recaptured leaving the marsh; the greatest number exited during August. Since there was also a large emigration of white suckers in the fall, the spring migrants could have been overlooked if there had been significant tag loss.

Walleye - Walleye movements within the Saskeram Marshes appeared to be restricted to only their spawning period. Of the 107 adult walleyes tagged and released into the marsh from May 17-28, 1983, eleven were recaptured between June 11 and 27 leaving the marshes. It is believed that most, if not all walleyes left the marshes within a month's time. Several recaptures were made at points downstream of Bracken Dam,

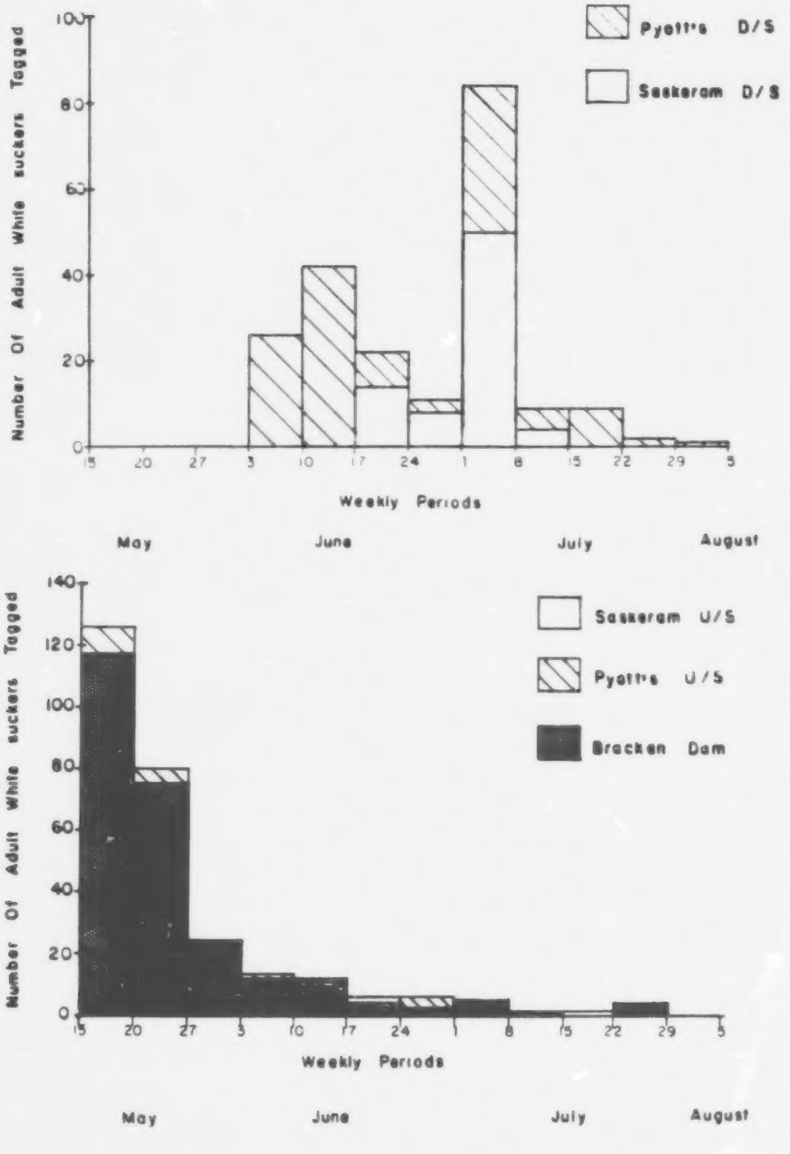

Fig. 22. Numbers of white suckers tagged and released at the Bracken Dam, Pyott's Crossing and Saskeram Lake outlet traps during weekly periods from May through August, 1983.

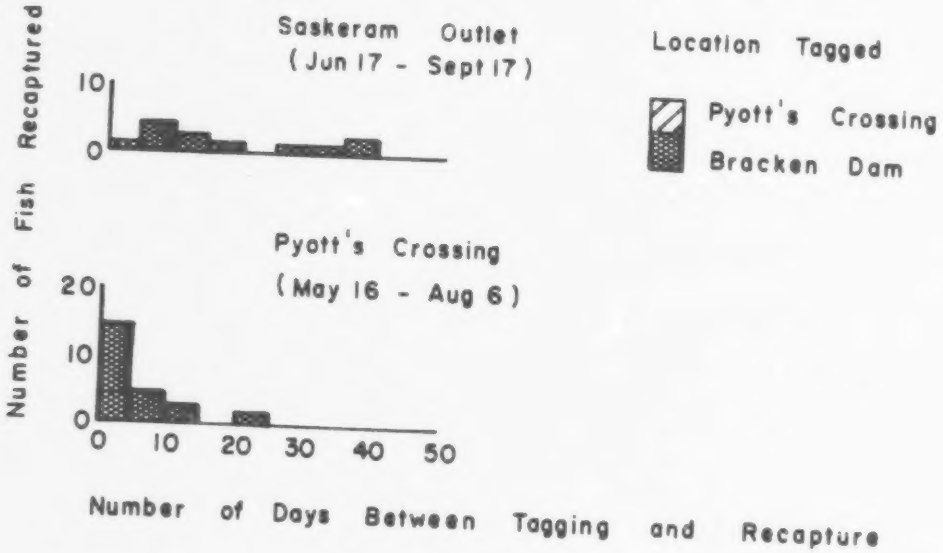

Fig. 23. Upstream net recaptures of white suckers tagged and released at Bracken Dam and Pyott's Crossing in 1983. Dates in parentheses are the times nets at those locations were in operation.

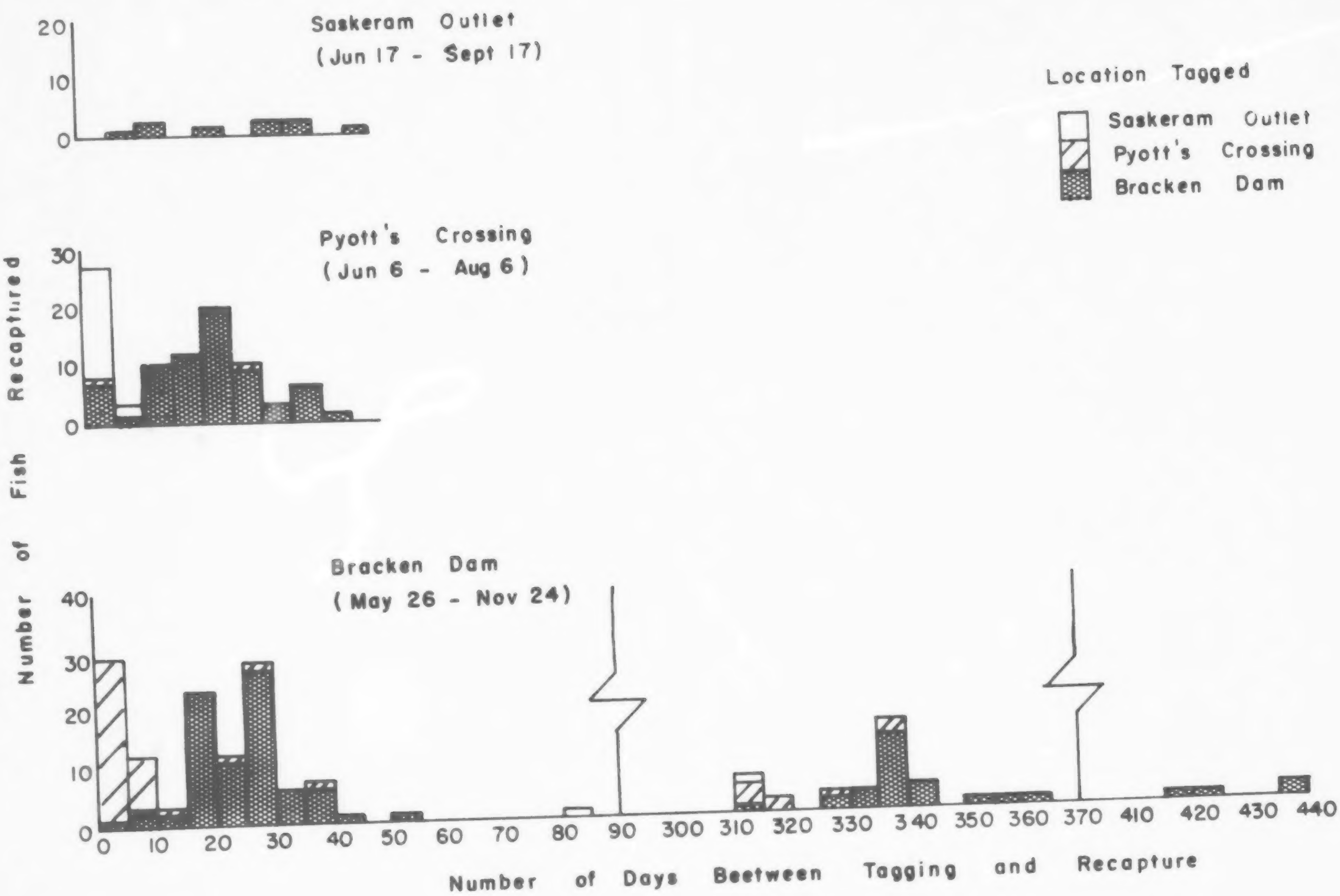

Fig. 24. Downstream net recaptures in 1983 and 1984 of white suckers tagged and released at Bracken Dam, Pyott's Crossing and Saskeram Lake outlet in 1983. Dates in parentheses are the times nets at those locations were in operation.

which indicated that some walleyes left the marshes unnoticed. Two walleyes tagged in 1983 were recaptured in the 1984 spawning run. None of the 27 walleyes released at Bracken Dam in 1984 was recaptured.

Carp - In 1983, 63 of the 68 carp caught in the Bracken Dam fish ladder were tagged and released into the Saskeram Marshes. The remainder escaped unmarked into the marshes. These fish may have been subsequently tagged at the Pyott's Crossing or Saskeram Lake outlet nets. Twelve carp were tagged at these points; mostly at the Saskeram Lake outlet downstream trap during late June and early July. Of the 63 carp tagged at Bracken Dam, 6 (10%) were recaptured. All of these recaptures, except two, were made in the Bracken Dam spillway trap between June 19 and 30. Two carp were caught at Bracken Dam in 1984, moving upstream during the carp spawning run. These results suggest the carp may not remain long in the Saskeram Marshes and move out within a month after entering the system. There were no recaptures of the 22 carp tagged and released at Bracken Dam in 1984.

Fish Movements Out of the Saskeram Marshes

Results obtained from the monitoring of the outmigration of fish from the Saskeram Marshes may have been biased not only by the variations in methods used, but also by events which occurred during the assessment. For example, the outflow at Bracken Dam was not as effectively screened in 1983 as it was in 1984. In 1983, only one spillway trap was used, whereas two were employed in 1984. In 1983, the Bracken Dam fish ladder was not used to capture outward moving fish until September 21; conversion of the fish ladder to a downstream trap took place on July 11, 1984. Finally, there was considerably more water spilled at Bracken Dam in 1983 than in 1984. As previously noted, several bays were left partially open from May 15 - August 13, 1983. Except for the water released through the fish ladder and spillway traps, there were no releases from Bracken Dam after June 4, 1984. In both years, trouble was also experienced in keeping the downstream fish ladder trap in place. Occasional problems were also encountered with spillway traps breaking. Consequently, the numbers of fish recorded as leaving the Saskeram Marshes represent minimum estimates of emigration and the area's overall contribution to fish stocks in the Saskatchewan River.

The monitoring of fish emigration was most successful for pike and suckers. Adults and juveniles of both species were readily captured at Bracken Dam (Appendices V to VII). Most of the pike caught were juvenile fish (Table 11) and primarily young-of-the-year fish. White suckers leaving the Saskeram Marshes were primarily adults. Juvenile suckers, unlike pike, were represented by more than one cohort. Single specimens of juvenile walleye, yellow perch, carp and goldeye were recorded in the study area in the 2 years of the study. Attempts to capture drifting larvae of such species as walleye and white sucker were unsuccessful. Only stickleback and cyprinid larvae were caught in drift nets set just above Bracken Dam. The following text presents the patterns of outmigration exhibited by adult and juvenile pike and white suckers.

Adult pike - The preponderance of adult fish intercepted while leaving the Saskeram Marshes in both 1983 and 1984 were untagged (Fig. 25). The proportion of tagged to untagged fish was greater in 1983 than in 1984. The distribution of tagged fish recoveries over time was

Table 11. Total numbers of juvenile and adult pike and white suckers observed leaving the Saskeram Marshes at Bracken Dam throughout 1983 and 1984.

		Northern pike		White sucker	
		Adult	Juvenile	Adult	Juvenile
1983	Fish ladder	240	27,291	7	240
	Spillway trap	296	7462	210	109
	Totals	536	34,753	217	349
1984	Fish ladder	895	14,692	718	55
	S. Spillway trap	755	14,668	30	82
	N. Spillway trap	200	15,005	21	141
	Totals	1,850	44,365	769	278

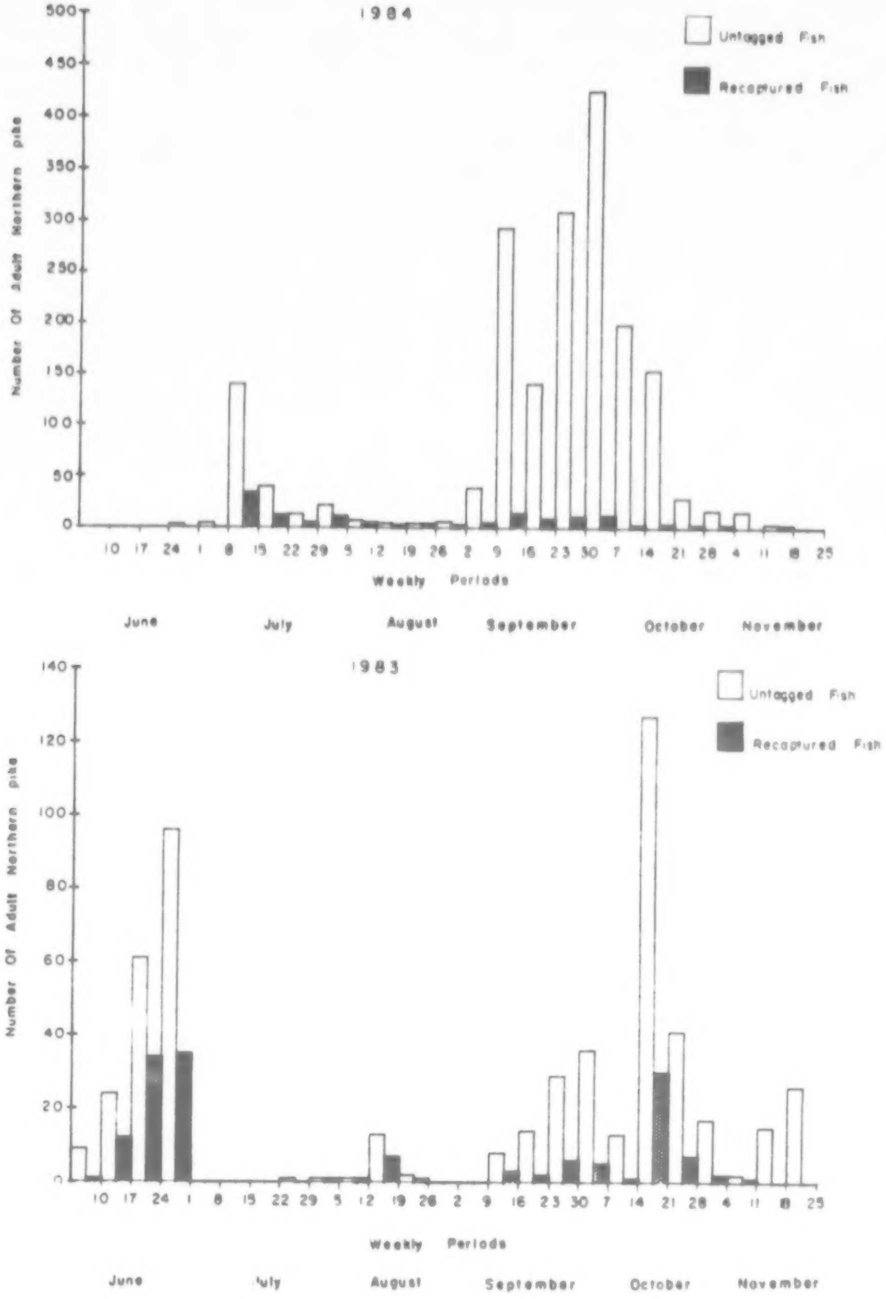

Fig. 25. Weekly catches of adult northern pike moving downstream past Bracken Dam through the period June to November, 1983 and 1984.

similar to variations in catches of untagged fish; i.e. more recaptures were made when large numbers of untagged fish were caught. This suggests that both groups of fish were responding to similar factors which were stimulating outward movements.

In 1983, a short burst of outward movement was observed during the last part of June. Both tagged and untagged pike were present in this movement. The cause of this movement is not known, but may simply represent a postspawning downstream migration. It is unlikely that this movement was stimulated solely by spilling operations at Bracken Dam. Spilling at Bracken Dam continued through July and early August and there was no marked exodus at that time. A peak in outward movement was observed during the second week of July in 1984. The causal agents in this situation are unknown. Discharges at Bracken Dam had been greatly reduced at this time and water temperatures had not yet reached their summer maximum.

Most adult pike left the Saskeram Marshes between late summer and early autumn. In both years, the exodus began by September 9 (Fig. 25), but the modal period of greatest movement varied. The mode occurred two weeks later (October 14) in 1983 compared to 1984 (September 30). The outmigration of adult pike appeared to be over by the end of November in both years. This curtailment of movement was coincident with water tempertures reaching 4°C (Appendix II & III). The decline in outward moving pike occurred much more abruptly in 1984 than in 1983. This was related to a much earlier freeze-up and onset of anoxic conditions in the marshes in 1984. Freeze-up had occurred on the Saskeram Marshes by October 31, 1984, whereas in 1983 it was approximately one month later.

A greater number of unmarked adult pike left the Saskeram Marshes in 1984 compared to 1983. A significant percentage (∿10%) of the untagged pike were considerably larger than the adult fish observed in the spring spawning run at Bracken Dam. Since appreciable volumes of water, originating from Cut Beaver Lake and the Saskatchewan River, were being released, at Cumberland Dam, it is believed that many of the untagged pike were fish that had been either flushed from or carried through the Cumberland Marshes.

Juvenile pike - Over 80,000 juvenile pike moved out of the Saskeram Marshes in the two years of this study. Considering equipment problems encountered in both years, the escapement of juveniles may have been in excess of 100,000. Comparison of the catches made over time in the two years indicates that the exodus of young pike from the area is remarkably predictable (Fig. 26). This outmigration began between the latter part of September and the first week of October. This movement may be triggered by a drop in water temperature to below 10°C. Peak movements occurred from approximately mid-October to mid-November. Dissolved oxygen levels evidently controlled the continuation of the outward migration of young pike. In 1983, the outmigration did not stop until the middle of December. Dissolved oxygen levels within the lower Birch River at this time were still in the order of 1.0 mg. l^{-1}. Oxygen levels recorded in the vicinity of Saskeram Lake on December 13 were below 0.5 mg. l^{-1} and there was a detectable sulphide odour in the water. In 1984, the outmigration ceased abruptly after mid-November. By November 13, the Saskeram Marshes had been frozen over and water leaving the marshes had a noticeable sulphide odour. Dissolved oxygen

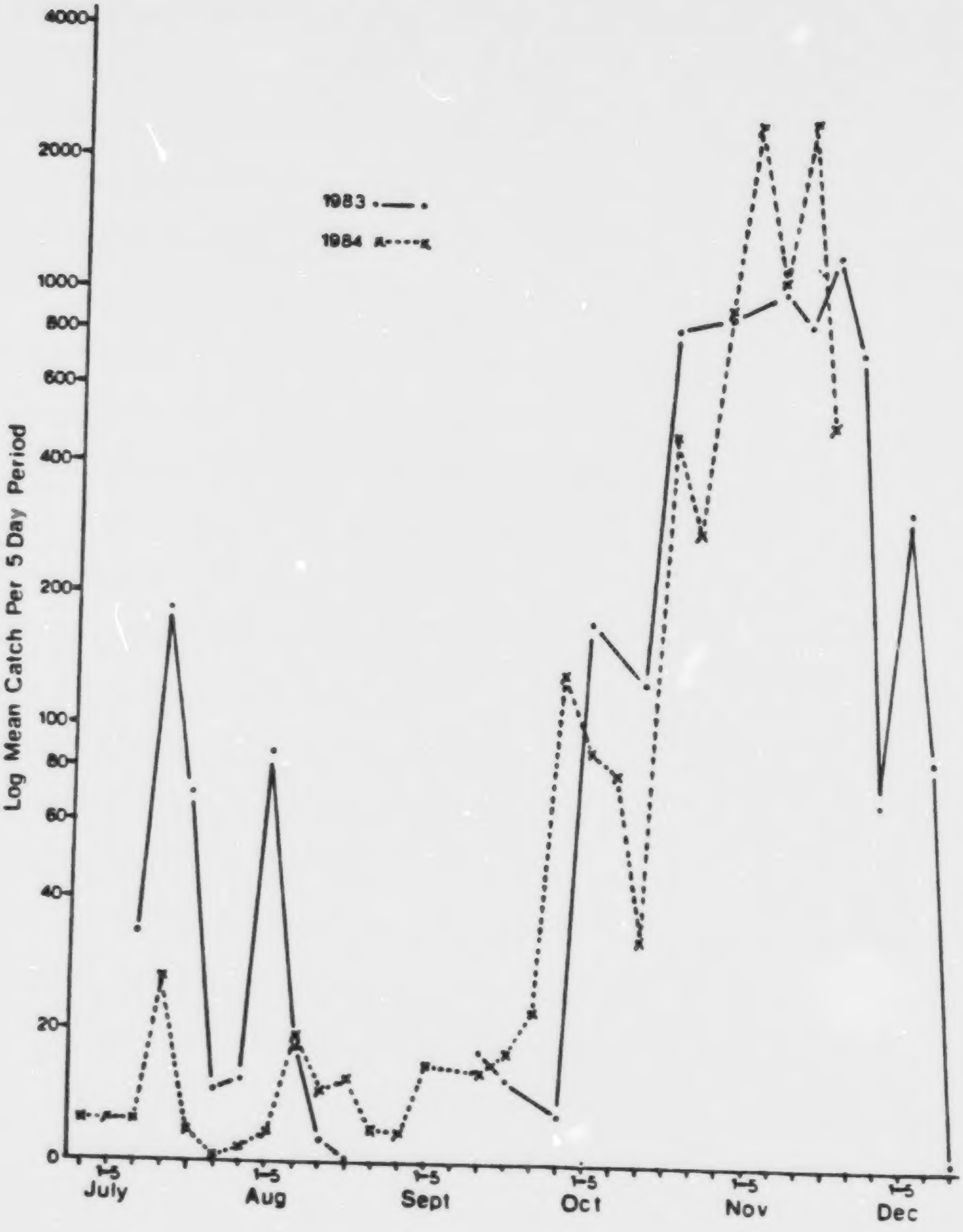

Fig. 26. The outmigration of young-of-the-year pike from the Saskeram Marshes July through December in 1983 and 1984, as indicated by mean catches at Bracken Dam per 5 - day periods.

levels in surface water above Bracken Dam dropped to less than 1.0 mg. l^{-1} by November 17.

Adult white suckers - The outmigration of adult white suckers from the Saskeram Marshes in 1983 appeared different from outward movements observed in 1984. In 1983, many of the tagged suckers were recaptured leaving the marshes during the latter part of June (Fig. 27), about a month after their spawning run began. At the same time, there was an exodus of large numbers of unmarked fish. Following this pulse in activity, no further catches of outward moving adult suckers were made at Bracken Dam until mid-October. Only occasional catches were made from then to mid-November.

The spawning-run suckers which moved into the Saskeram Marshes in 1984 probably left the marshes before monitoring of downstream movements began on June 24. Considerable volumes of water were being spilled from one radial gate and several stoplog bays in Bracken Dam beginning on May 2. The radial gate was closed May 22, but some stoplogs were left out in four bays. Except for flows through the fish ladder, releases at Bracken Dam were shut down on June 4. During this period (May 2 - June 4) many of the suckers which moved into the Saskeram Marshes during late April may have left undetected. Unlike 1983, however, some tagged suckers were recaptured moving out in July and August (Fig. 27).

In contrast to the 1983 results, large quantities of white suckers were noted leaving the Saskeram Marshes from late August through October in 1984. As will be noted later, many of these suckers were of much smaller size than the fish observed moving into the marshes during

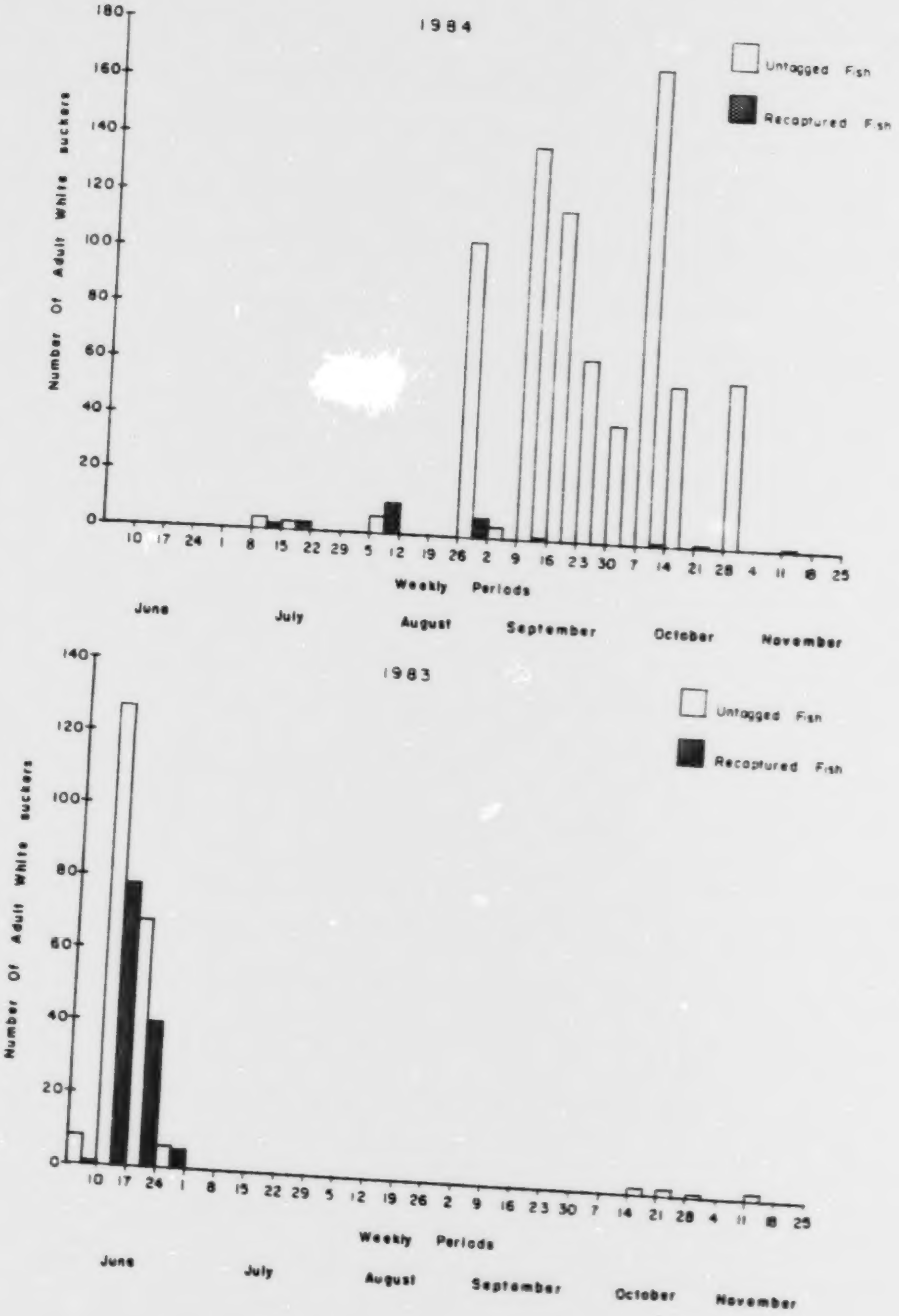

Fig. 27. Weekly catches of adult white suckers moving downstream past Bracken Dam through the period June to November, 1983 and 1984.

April and May. It is believed that many of these fish were introduced to the Saskeram Marshes either from the Cumberland Marshes or the Saskatchewan River - Old Channel via the Cut Beaver Lake reservoir. "Scars" resulting from the regeneration of lost scales were frequently observed on the smaller suckers passing over Bracken Dam during the late summer. These scars suggested that the fish had been caught in heavy netting, such as that used at the outlet of Cut Beaver Lake, and had lost some scales around the dorsal fin. Adult white suckers continued to leave the Saskeram Marshes in appreciable numbers until the end of October. The duration of these outward movements was consistent with water management measures on the Cumberland Marshes. Discharges from the Saskatchewan River into the Cumberland Marshes continued into October and the Cumberland Dam was not closed until October 10.

Juvenile white suckers - Approximately the same numbers of juvenile white suckers left the Saskeram Marshes in both years; 349 in 1983 and 278 in 1984. Any suckers which were less than 30 cm in length were classified as juveniles; this criterion probably encompassed at least two and probably three cohorts. Although the outmigration of juvenile suckers was more sporadic than that of juvenile pike, there was a tendency toward two peaks in their migratory activity. The first peak occurred from about the first of July to mid-August (Fig. 28). This peak appears to be associated with the mid-summer maxima in water temperatures (Appendices II & III). Although the fall peak in movement, from mid-October to mid-November seems much less defined, it is associated in both years with a drop in water temperature to below 5°C.

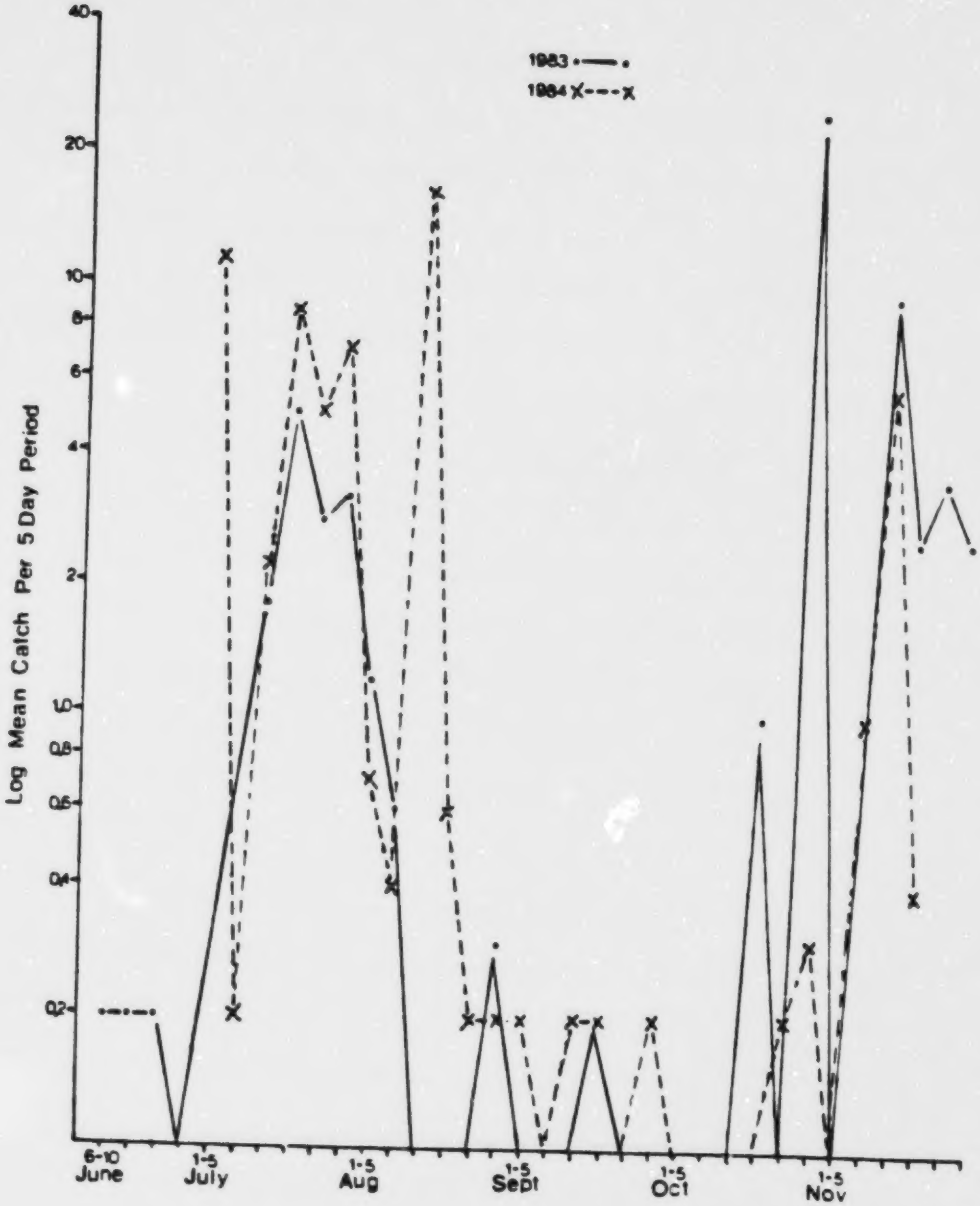

Fig. 28. The outmigration on juvenile white suckers from the Saskeram Marshes from June through November in 1983 and 1984, as indicated by mean catches at Bracken Dam per 5 - day periods.

Fish Movements Outside the Saskeram Marshes

In order to document the movements of tagged fish leaving the Saskeram Marshes, we relied on returns from anglers and commercial fishermen. Anglers were given a certificate and a crest for tag returns, while commercial fishermen were given a $5 reward for each tag return. This reliance on public assistance for tag recoveries obviously biased the results to some degree. For example, since suckers and carp are not pursued by sport fishermen, commercial fishermen had to be relied upon for those returns. Most of the suckers and carp tagged were generally too large to be caught in the commercial gill nets and therefore no returns were obtained which would help describe their movements within the Saskatchewan River Delta.[1] Also, commercial fishermen in the area, prompted by the prospects of obtaining reward money, actively pursued tagged pike off the Carrot River mouth, at a time when the pike seemed to be particularly concentrated in the area. In many cases these pike recaptures were made using angling gear rather than gill nets. Finally, fishing effort by anglers and commercial fishermen is not uniform throughout the Delta, so recaptures, especially from areas more removed from the Saskeram Marshes, may not be totally representative of timing of movements or concentrations within given areas. Consideration of the tagged fish recoveries outside the Saskeram Marshes, however, does provide some insight into the importance of the marshes to fish stocks throughout the Saskatchewan River Delta. Following are the movements of northern pike and walleyes after they have left the Saskeram Marshes, as deduced from recoveries of fish tagged primarily in 1983 and 1984. Relatively small numbers of tag recoveries of fish released in 1981 and 1982 are also included. Only recoveries up to March 31, 1985 were considered.

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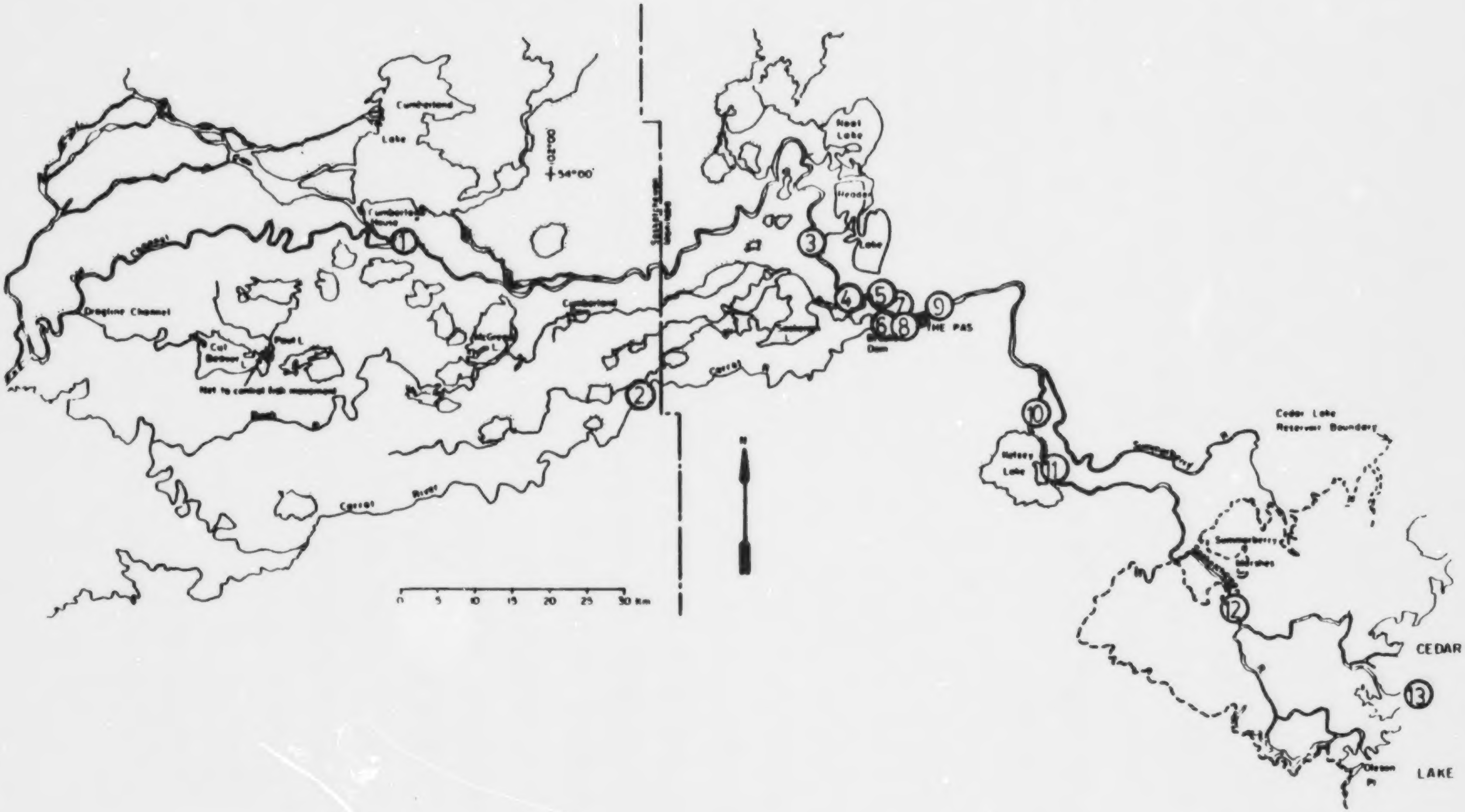
[1] Subsequent to the preparation of this report one white sucker was captured from Cumberland Lake, Saskatchewan, by a commercial fisherman.

Northern pike - Tagged pike released at Bracken Dam or Saskeram Lake were recovered in the Saskatchewan River as far upstream as Cumberland House in Saskatchewan and downstream as far as Cedar Lake, about 90 km from The Pas (Fig. 29, Table 12). These extreme movements were accomplished in anywhere from two weeks to eight months. Most of the pike recoveries were made at Big Eddy and around the Carrot River mouth (Table 12). Most of these recoveries (>85%) were of tags released in 1984. Since many of these recoveries were made by local commercial fishermen and since they were receiving a substantial reward for the tag return, these results are obviously biased. Note that in 1983 a relatively higher proportion of tagged pike recaptures were made just below Bracken Dam (Area 6). All of these recoveries were by anglers; commercial fishermen on the Saskatchewan River may not have been fully aware of the reward offered for tag returns at this time or where the fish were concentrated. Although the tag returns were biased, the results do indicate that, on the whole, most of the pike leaving the Saskeram Marshes did not move too far from the area. Many of the recaptures made at the Carrot River mouth occurred during the winter months and especially March. The high frequency of recoveries around the confluence of the Saskatchewan and Carrot rivers and may therefore represent a pre-spawning aggregation. There did not appear to be any association between the direction or distance pike moved and time between release and recapture.


Cumberland
Lake
Cumberland House
Channel
Dragline Channel
Cut Beaver L.
Pool L.
Not to control fish movement
Cumberland
Saskatchewan
Manitoba
102°00'
54°00'
Neal Lake
Lake
Carrot
Carrot River
Dam
THE PAS
Halcey Lake
Summerberry
Summerberry Marshes
Cedar Lake Reservoir Boundary
CEDAR
LAKE
Oleson Pt
N
0
5
10
15
20
25
30 Km
1
2
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12
13

Fig. 29. Locations of tagged pike recaptures in the Saskatchewan River Delta outside of the Saskeram Marshes.

Table 12. Summary of pike tag returns from downstream Bracken Dam showing recapture locations, distance from Bracken Dam, numbers and days at large.

	Location of recapture	Distance from Bracken Dam (km)	Year of tagging	Number recaptured	Time between tagging & recapture (days)	
					mean	range
1.	Cumberland House	108.0	1984	1	17.0	
2.	Bainbridge Creek	44.4	1984	1	28.0	
3.	Reader Outlet	19.6	1984	6	67.3	24 - 170
4.	Whitefish Creek	8.2	1983	6	324.8	285 - 380
			1984	7	41.1	1 - 150
5.	Big Eddy	6.3	1981 - 82	13	171.8	5 - 762
			1983	3	134.0	37 - 309
			1984	92	45.9	2 - 220
6.	Birch River Mouth	0.1	1981 - 82	5	451.6	4 - 766
			1983	42	137.9	2 - 404
			1984	27	52.1	3 - 239
7.	Carrot R. Mouth	1.3	1983	5	141.6	5 - 274
			1984	84	94.5	6 - 259
8.	Knapp Dam	5.1	1983	14	65.3	6 - 356
			1984	13	88.0	2 - 145
9.	D. U. Barge	7.6	1981 - 82	2	770.0	763 - 777
			1983	2	345.5	336 - 355
			1984	2	90.0	75 - 105
10.	Wooden Tent	38.8	1983	1	218.0	
			1984	12	81.3	13 - 278
11.	Kelsey Lake	47.6	1981 - 82	4	273.3	31 - 368
12.	Pine Bluff	85.8	1981 - 82	2	92.5	29 - 156
13.	Cedar Lake	88.5	1981 - 82	2	435.5	254 - 617
			1984	1	251.0	

Walleyes - Walleyes released from the Saskeram Marshes exhibited the same general pattern of distribution shown by pike (Table 13). There was also a tendency for recaptures to be concentrated in the vicinity of the Saskatchewan and Carrot River confluence. Although the numbers of recoveries are small, it is noteworthy that most recaptures in a single area came from below Bracken Dam and that the average time between tagging and recapture is almost exactly one year. Since the walleyes were only tagged during their spawning season, these results suggests that the fish have homed back to the area in the following spring to spawn once again.

Fish Homing Movements to the Saskeram Marshes

Observations on the number of tagged fish recaptures at the Bracken Dam fish ladder each spring provided some indications of the homing of the various species to the Saskeram Marshes. The number of tag recoveries in the fish spawning runs at Bracken Dam between 1982 and 1984 reveals that at least a certain number of repeat spawners return (Table 14). This is particularly true for white suckers and pike, where 50 or more of the fish tagged in 1983 returned in the 1984 run. Considering the possibility that all fish may not spawn each year and an unknown amount of tag loss, these returns may have been higher. Certainly there may be a greater return of walleyes to the Birch River. However, these returns could be overlooked since there are annual differences in the number of walleyes which show a propensity to move through Bracken Dam into the Saskeram Marshes. Large numbers of walleyes were being angled in the Birch River below Bracken Dam in April 1984, but few walleyes showed any inclination at that time to move into the Saskeram Marshes.

Table 13. Summary of walleye tag returns downstream from Bracken Dam showing recapture location, distance from Bracken Dam, numbers and days at large.

Location of recapture	Distance from Bracken Dam (km)	Number recaptured	Time between tagging and recapture (days	
			mean	range
Big Bend	38.8	3	51.3	32 - 61
Whitefish Creek	8.2	1	61.0	
Big Eddy	6.3	4	400.8	153 - 686
Birch River Mouth	0.1	9	372.9	31 - 1236
Knapp Dam	5.1	3	412.0	58 - 760
Bignell Bridge	6.3	1	397.0	
D. U. Barge	7.6	1	38.0	
Rahl's Island	17.1	3	379.3	214 - 671
Pine Bluff	85.8	3	423.3	156 - 593
Saskatchewan R. mouth	87.1	1	352.0	
Cedar Lake	88.5	2	61.0	61 - 61

Table 14. Summary of tag recoveries in the fish spawning runs at Bracken Dam between 1982 and 1984.

Year of tagging and number	Number recaptured in Bracken Dam spawning run		
	1982	1983	1984
Northern pike			
1981/82 (1700)	-	4	5
1983 (1644)	-	-	50
White sucker			
1983 (485)	-	-	53
Walleye			
1981/82 (360)	3	-	-
1983 (107)	-	-	2
Carp			
1983 (76)	-	-	2

Evidence for homing or the cyclical movements of a discreet population of northern pike to and from the Saskeram Marshes is provided by an examination of the distribution over time of our own recoveries of pike tagged and released into the Saskeram Marshes in 1984 (Fig. 30). Pike recaptured at Bracken Dam approximately 240 - 300 days after release were generally individuals which were moving into the Saskeram Marshes to spawn. Recoveries after 300 days represented those adult pike which were moving out of the marsh in early summer (June - July). Those fish caught after 400 days represented pike which left the Saskeram Marshes in October and November.

FISH POPULATION CHARACTERISTICS

Since the two species of large fish most frequently caught at Bracken Dam and in the Saskeram Marshes were northern pike and white sucker, the description of vital statistics on fish populations is devoted primarily to these species. Recapture data, adequate for population size estimations, were available for only pike and suckers. Because of the small sample sizes, the population parameters considered for walleye, carp and goldeye, were limited. In the case of these latter species, only growth and survival/mortality parameters were examined.

Population Size Estimates

Intensive mark and recapture efforts, sufficient for population estimates, were made only in 1983. The release and recaptures of adult pike and white suckers at Bracken Dam and in the lower Birch River are presented Appendix VIII. Appendices IX and X include the computations for the Schumacher - Eschmeyer population estimates.

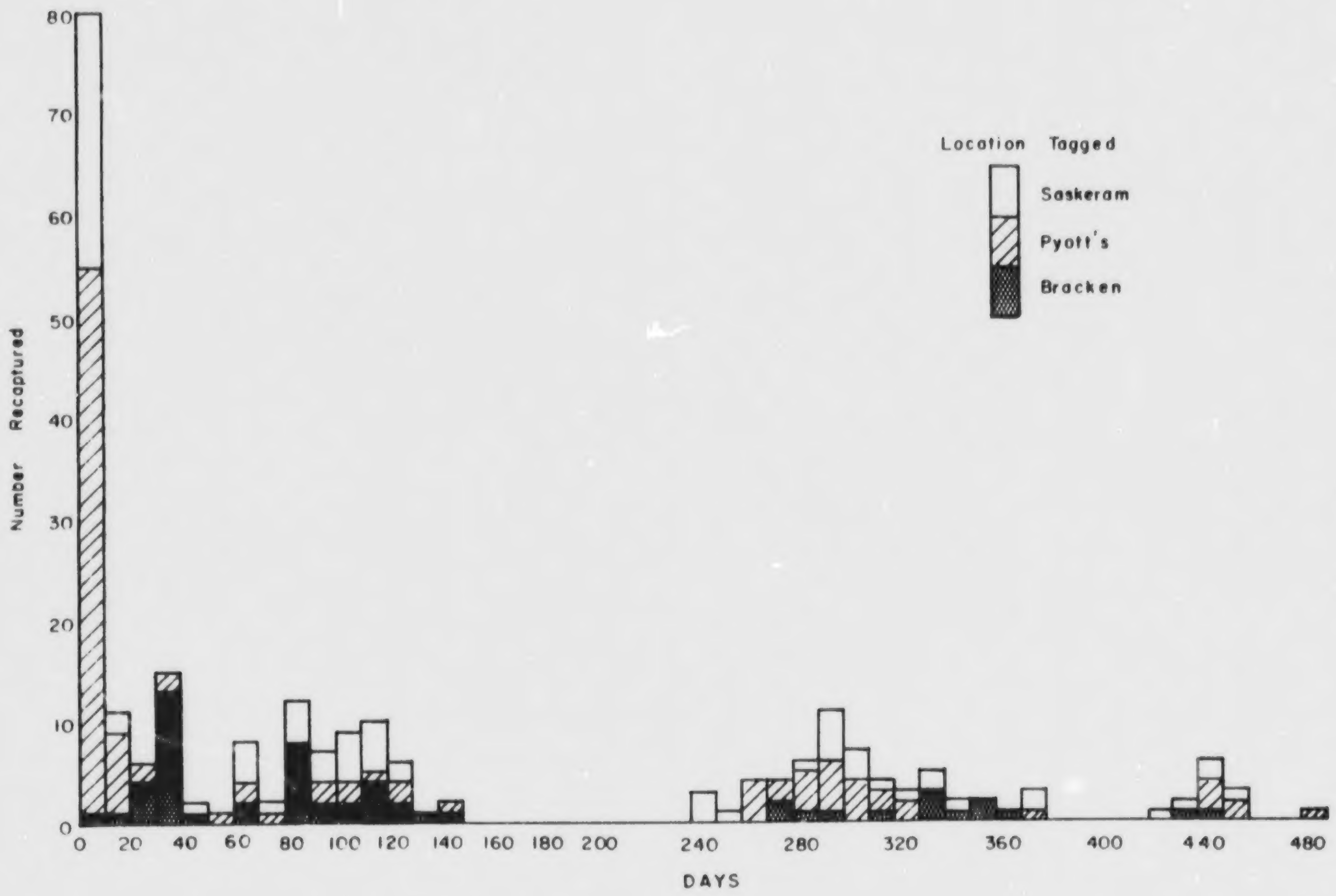

Fig. 30. 1983 and 1984 recaptures of adult pike tagged and released in 1983 at Bracken Dam, Pyott's Crossing and Saskeram Lake outlet.

Northern pike - The size of the adult pike population in the lower Birch River between Bracken Dam and Saskeram Lake was estimated for five different time periods from the onset of the spawning run (May 15) to the beginning of the fall outmigration of adult pike (September 3). The highest estimate (~3400 fish) was obtained during the spawning period, while the lowest estimate (2030 fish) was observed in the next period, from May 15 - June 30 (Table 15). The larger estimate obtained during the May 15 - 31 period was due to the low number of recaptures relative to the total catch; tag recaptures represented only 4 per cent of the total catch of pike made by May 31. The few recaptures were probably due to the spawning dispersion of tagged pike throughout the Saskeram Marshes and away from our capture gear. The lower estimate for the May 15 - June 30 period was due to a higher percentage of recaptures in the catch (18.6%). In the next three periods, the estimates of population rose to just over 3000 individuals and remained relatively stable.

It should be noted that a large number of recaptures was made relative to the daily catches during the latter part of June (Appendix IX a). This would contribute to a lower population estimate. During the last half of June there was also a significant increase in the number of tagged fish injected into the system. Although there was some response to this in the form of increased recaptures, the addition of more tags would tend to increase the population estimate. The fact that this did not happen was possibly due to the loss of tagged pike from the system. As already noted, many of the fish tagged in the lower Birch River in June were oriented downstream. Therefore, many of the tagged fish may

Table 15. Schumacher - Eschmeyer estimates of adult pike populations in the lower Birch River during various time periods throughout the openwater period in 1983.

Time Period	Population Estimate	95 % Confidence Interval
May 15-May 31	3390	3250 - 3543
May 15-June 30	2030	1977 - 2086
May 15-July 31	3120	3016 - 3231
May 15-Aug. 23	3030	2933 - 3134
May 15-Sept. 3	3040	2942 - 3145

Table 16. Schumacher - Eschmeyer estimates of adult white sucker populations in the lower Birch River during various time periods in summer, 1983.

Period	Population Estimates	95 % Confidence Interval
May 16-May 31	1330	1151 - 1574
May 16-June 30	710	683 - 739
May 16-July 31	1080	1017 - 1151

have moved out of the system undetected. Although we recorded all tagged and untagged fish caught in our traps at Bracken Dam, we were unable to effectively strain all of the water that passed over the dam. This escapement may have been greater than we recorded, since large volumes of water (>4.0 m^3 sec^{-1}) were being spilled at Bracken Dam during early summer (C. Smith, personal communication). Appreciable numbers of tagged fish were also lost in June due to mortality in gill nets and to some extent in late July - early August due to summerkill conditions (Appendix VIII a). It is further recognized that some fish dropped their tags. Lost tags were occasionally found in trap nets. Since this happened, some fish also may have lost poorly anchored tags while swimming through the dense aquatic vegetation. Except for the net mortalities, tag losses cannot be quantified.

Population estimates determined during the last three time periods presented in Table 15 were stable around 3000 to 3100 individuals. This stability was likely due to a reduction in tag loss from the system and a good random mix of tagged fish remaining within the system. As indicated in Fig. 25, there was little outward movement of adult pike during July and August, despite the continuation of appreciable discharges from Bracken Dam during this period. On the contrary, there was an increased movement of adult pike into the Saskeram Marshes during late July (Fig. 19); these fish were tagged before they were released into the marshes. The uniform population estimates suggest they may be close to the actual size of the pike population in the Saskeram area. The estimate of 3000 - 3100 pike is only approximately 600 fish more than the total number of adult pike handled in 1983. It should also be noted that of the 1644 pike tagged in 1983, almost 45 per cent (716) were recaptured. This high ratio of recoveries would permit a good estimate of the population size despite the complexities introduced by adult pike entering and leaving the system at different times.

White suckers - Estimates of white sucker populations in the lower Birch River portion of the Saskeram Marshes over different time periods to the end of July exhibited the same trends observed for pike. The population estimates for the May 15 - 31 spawning run period was about twice the size of the estimate for the following period (Table 16). The estimate for the May 16 - 31 period was approximately 1100 individuals. Population estimates could not be made for any time period beyond July 31, since most adult suckers had left the Saskeram Marshes by this time (Fig. 27) and there were too few catches and recaptures on which to base an estimate. The reasons for the trends in the population estimates of white suckers are likely the same as those offered for the pike estimates. The estimate of 1100 fish does not seem unrealistic since we handled in the order of 700 adult white suckers and 485 of those were tagged.

Age and Length Frequency Distributions

Age and length frequency histograms were plotted for pike, white suckers, walleyes and carp. Since large samples of pike and white suckers were obtained in one or both years, we were able to examine seasonal as well as annual and sexual differences in the population parameters for these two species. Walleye and carp samples of sufficient size were obtained only in spring, so the age and length distributions are solely characteristic of their spawning populations.

Northern pike - Except for several minor differences, the age and length frequency distributions for pike sampled from the Saskeram Marshes in 1983 and 1984 are very similar. In both years, young-of-the-year fish dominated the age distributions in samples and there were few fish older than 5 years (Fig. 31). The age frequency distribution of male and female pike were almost the same in both years. Old, large females were not a significant part of the populations. There was a distinct bimodality in the length frequency distribution in both years. Modes occurred between 20 and 30 cm and 30 and 50 cm. The first mode incorporated the young-of-the-year pike, whereas the second encompassed the adults.

Two very obvious differences between the 1983 and 1984 data were the poor representation of yearling pike in the 1983 sample and the shift to the right of the length frequency distribution. In 1983, the modes occurred in the 23 - 28 and 43 - 48 cm intervals, while they occurred in the 28 - 33 and 48 - 53 cm intervals in 1984. Another noticeable difference is the presence of much larger pike, especially females in the 1984 samples.

Considering the data for both sexes combined, the seasonal changes in the age and length frequency distributions of pike were similar in the two years. Samples taken during the spring spawning period and immediately after (April-May-June) consisted mainly of age groups 2, 3, 4 and 5 in 1983 and 1984 (Fig. 32). Age one pike were more strongly represented in the 1984 samples, particularly during the summer, compared to 1983. The modal length of pike in the 1984 spawning run was 5 cm larger than in 1983. Underyearling pike predominated in the summer

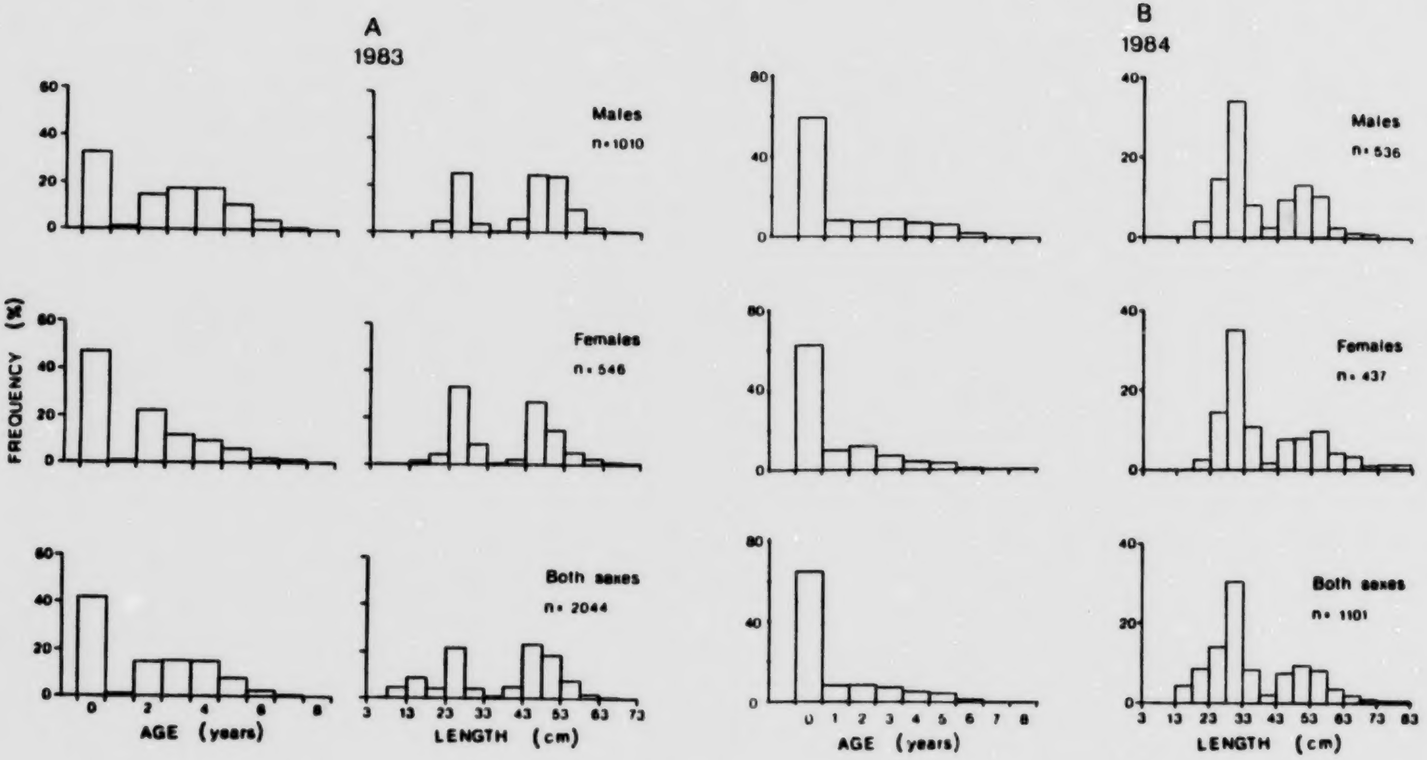

Fig. 31. Age and fork length frequency distribution of northern pike sampled from the Saskeram Marshes and at Bracken Dam for the periods May, 1983 - January, 1984 (A) and April - October, 1984 (B).

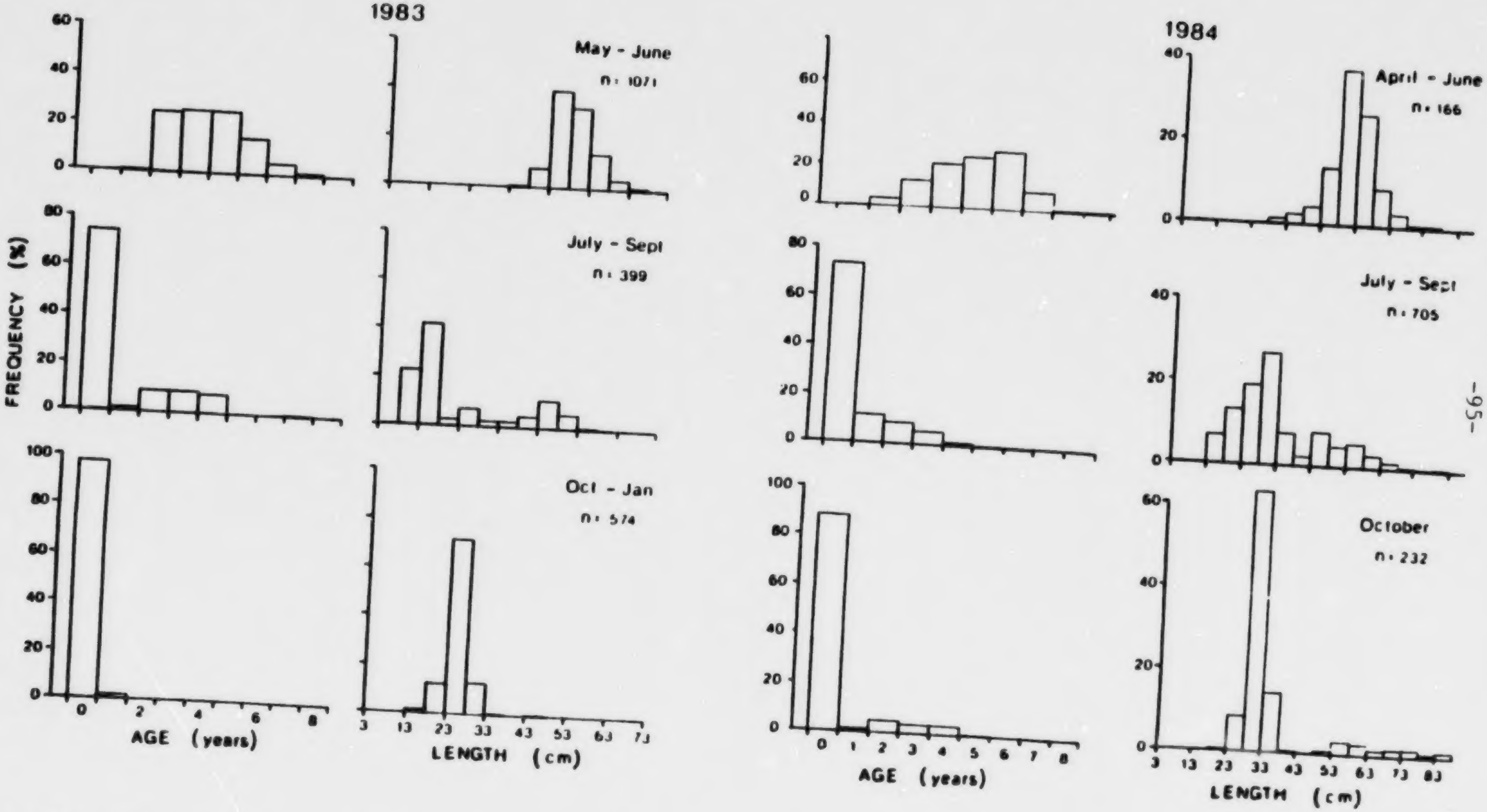

Fig. 32. Age and fork length frequency distribution of northern pike (sexes combined) sampled from the Saskeram Marshes and at Bracken Dam during the spring, summer and autumn in 1983 and 1984.

samples (July-September) taken in both years, although adult pike were still present in the Saskeram Marshes. The young-of-the-year pike appeared to be smaller in 1983. As will be noted later, this was because the 1983 samples of young-of-the-year pike were taken only during July and August. September samples were taken in 1984, and it was during this month that the young pike achieved their maximum growth. Some adult pike left the marshes in fall-early winter (October-January) in both years, but they were primarily sampled in 1984 since they were unlike the adults admitted to the marshes during the spawning run. Nonetheless, young-of-the-year pike were the most prevalent age group observed leaving the Saskeram Marshes before freeze-up. Young-of-the-year pike sampled during this time period in 1984 were generally about 5 cm larger than in 1983.

The differences in age and length frequencies of pike between 1983 and 1984 were due to annual variations and could not be attributed to any sexual differences in age composition or growth. Except for a discrepancy between the age composition of male and female pike during the spring in both years, the age and length frequencies of male pike during the spring, summer and fall seasons were similar to those observed for females (Figs. 33 & 34). In other words, both sexes were sampled without bias.

YOY pike - The length frequency distributions of young-of-the-year pike were examined on a monthly basis in 1983 and a biweekly basis in 1984. These size distributions indicate much better growth of young pike in 1984 (Fig. 35). In July 1983, most pike were less than 15 cm in fork length, while in 1984 the bulk of the fish were

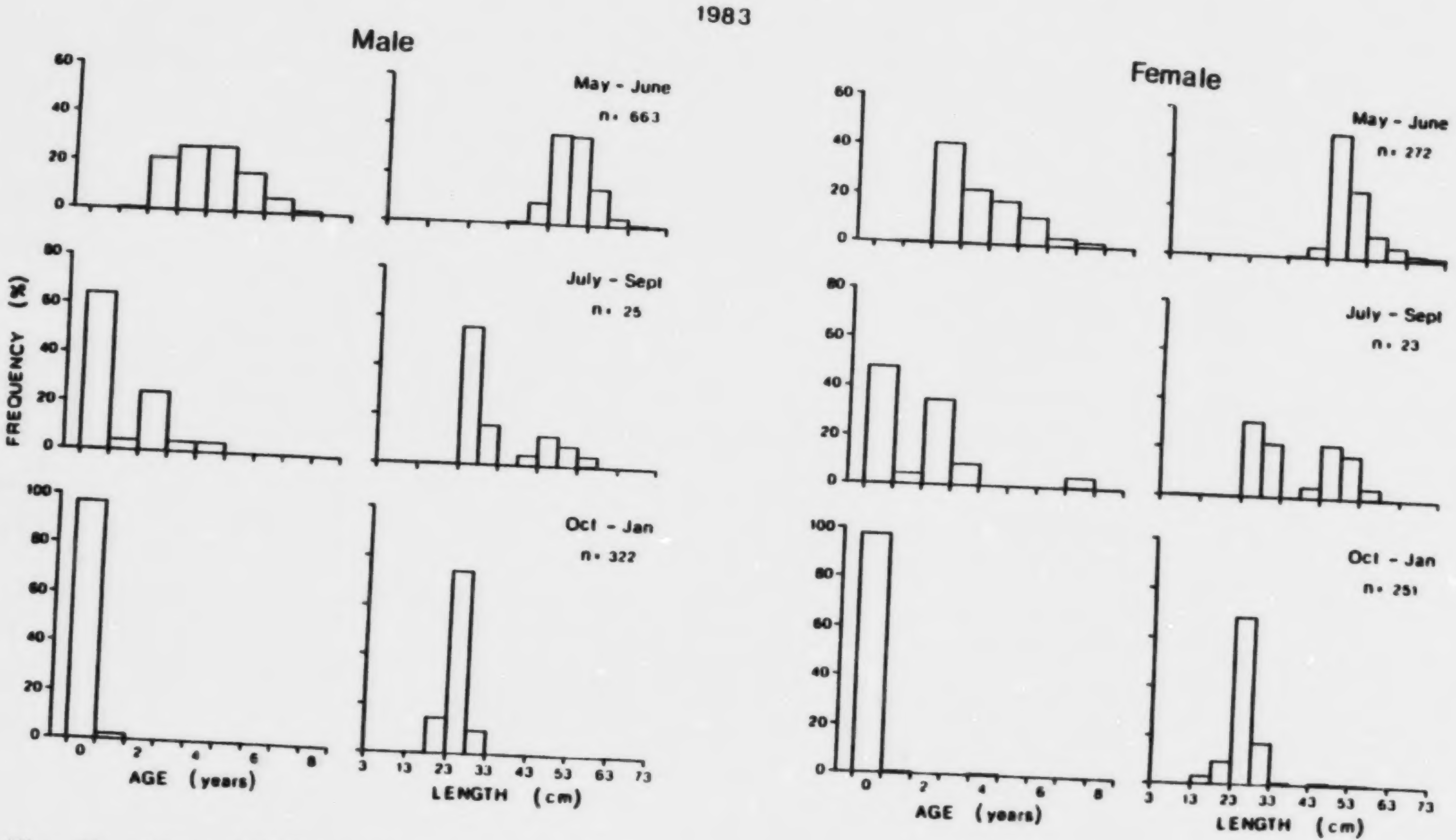

Fig. 33. Age and fork length frequency distribution of male and female northern pike sampled from the Saskeram Marshes and at Bracken Dam during the spring, summer and autumn seasons in 1983.

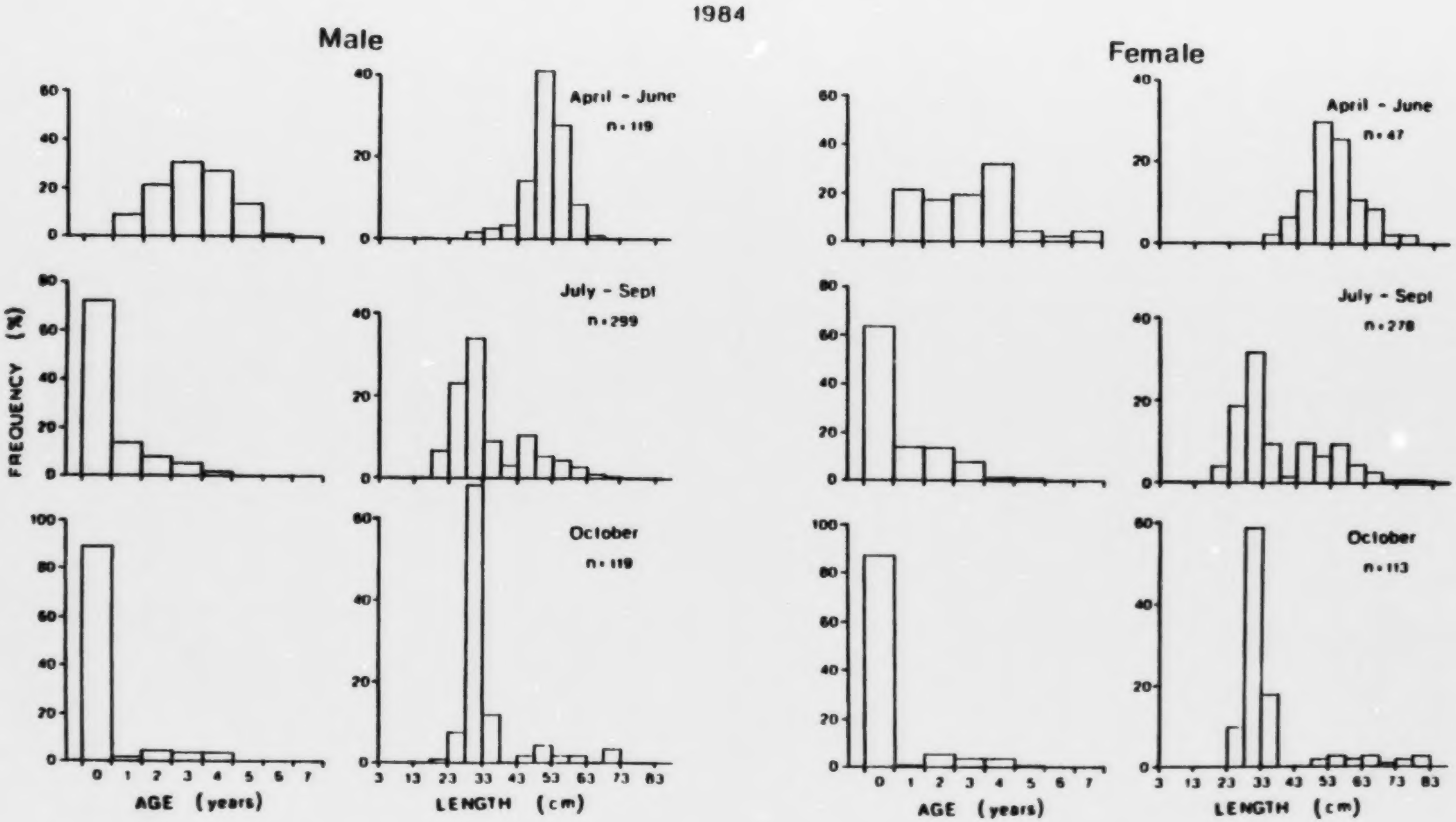

Fig. 34. Age and fork length frequency ditribution of male and female northern pike sampled from the Saskeram Marshes and at Bracken Dam during the spring, summer and autumn seasons in 1984.

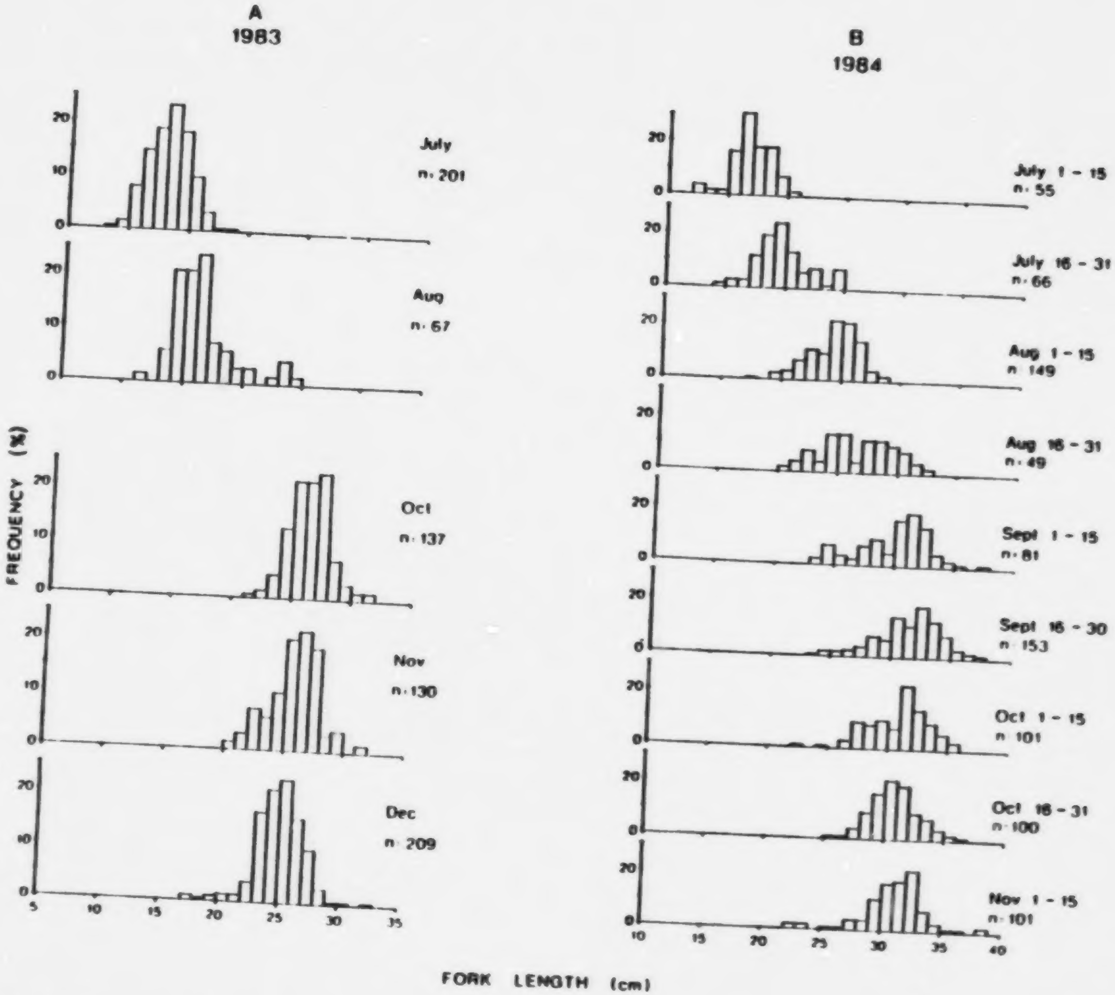

Fig. 35. Length frequency distrubution of young-of-the-year northern pike from the Saskeram Marshes for monthly periods in 1983 (A) and biweekly periods in 1984 (B)

over this size by mid-July and were approaching a length of 20 cm by the end of the month. The modal length of young pike in August, 1983 was only 16 cm, compared to approximately 25 cm in 1984. No samples were taken in September 1983, but those for 1984 indicate that growth in length of young-of-the-year pike peaked by mid-September. Except for slight shifts in the modes, the length frequency distributions remained relatively constant from October onward. The difference in growth rates in the two years was again reflected in the final size attained by the young pike; 1983 individuals were generally 5 cm smaller.

Based on the length frequency distrubutions for two samples of underyearling pike taken from the Cumberland Marshes on August 15 - 16 and October 23, 1984, it appeared that growth of young-of-the-year pike may have been faster there than in the Saskeram Marshes. The August sample, which was caught just upstream of Cumberland Dam, had a modal length of 30 cm (Fig. 36) and a mean length of 29.3 cm (Appendix XVIIIb). The modal length in the October sample, which was netted in the Beaton Lake area, was around 36 cm (Fig. 36). These average sizes are approximately 4 to 5 cm greater than those observed for pike from Saskeram Lake in 1984 (Fig. 35). However, since the samples from the Cumberland Marshes were taken by gillnets, they may have been biased for the larger fish.

Some of the 1983 samples of young-of-the-year pike were autopsied to determine sex. The length frequency distributions of males and females were similar. The modal of both groups was 25 cm (Fig. 37). There were, however, slightly more larger females than males which suggests the onset of a sexual dimorphism in growth.

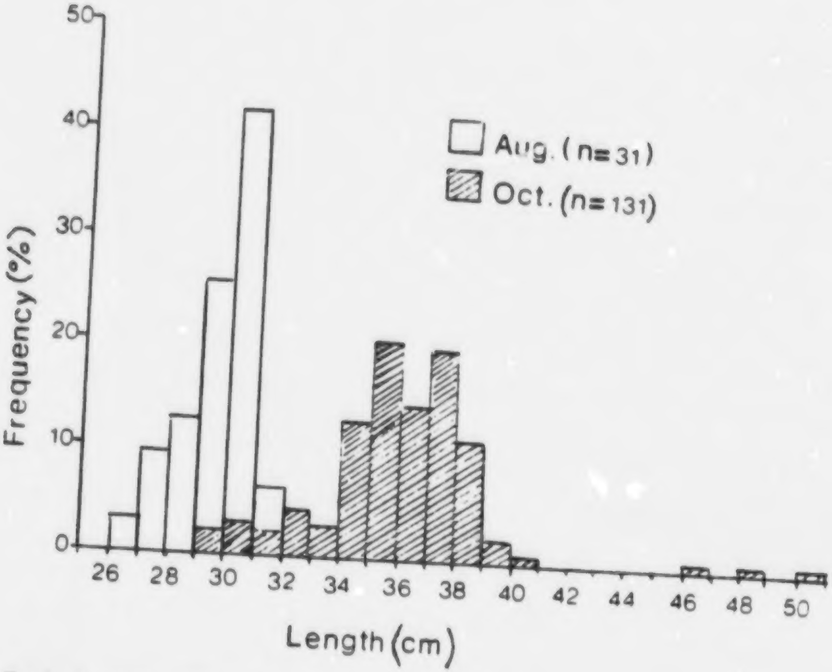

Fig. 36. Fork length frequency distributions of two samples of juvenile pike from the Cumberland Marshes in 1984. The several fish at the extreme right of the graph consisted of one or two year old fish; all others were young-of-the-year.

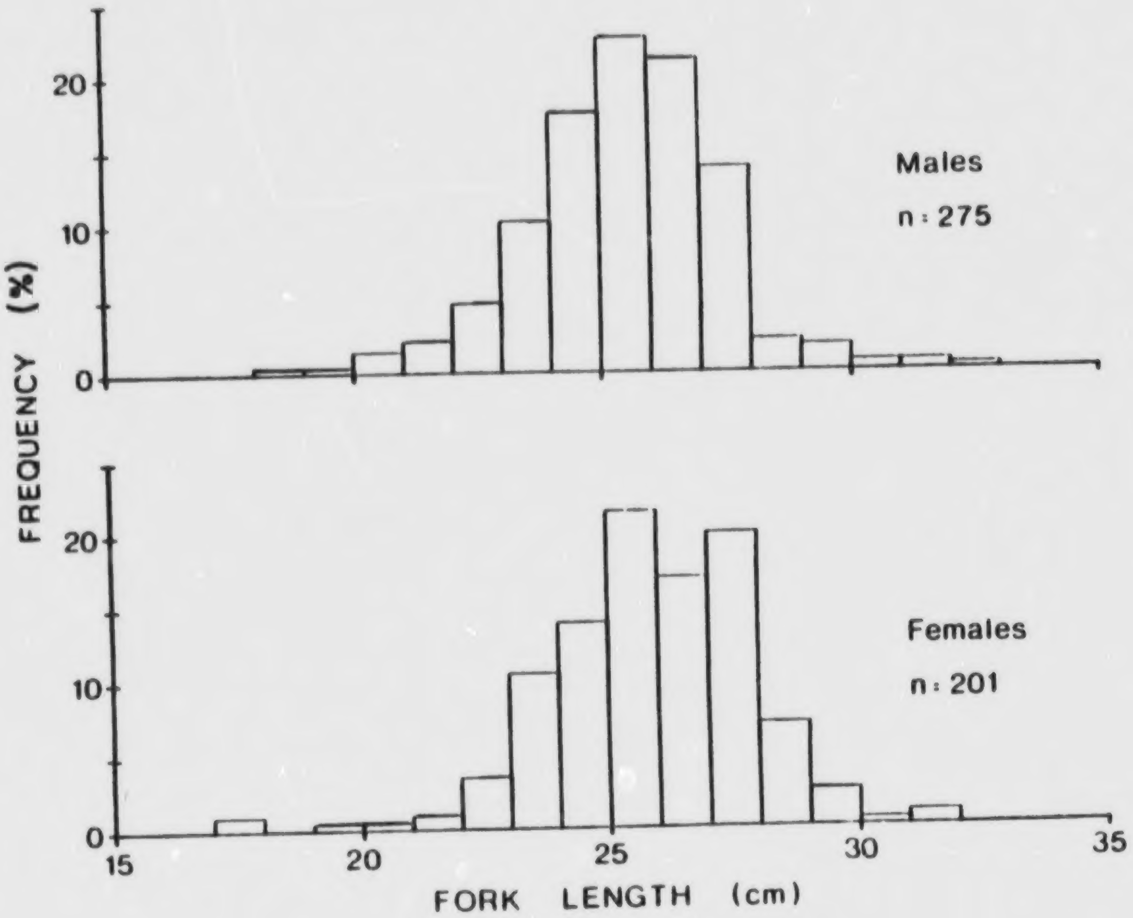

Fig. 37. Length frequency distribution of male and female young-of-the-year pike from the Saskeram Marshes sampled during October - December, 1983.

White suckers - Since ageing structures were not taken from suckers collected in 1983, between year comparisons can only be made for length frequency distributions. The 1983 and 1984 distributions were similar except for a high proportion of small fish (approximately 30 - 35 cm) in 1984 (Fig. 38). In both 1983 and 1984, the larger suckers ranged primarily between 40 and 50 cm in length and there tended to be more larger females than males. Although smaller suckers (i.e. ≤30 cm) were noted in 1983, they were not caught in the number taken in 1984. As previously noted, and illustrated in Fig. 39, the 30 - 35 cm long specimens were taken from August through October. These fish were caught on their exodus from the Saskeram Marshes. It is suspected that these small suckers came from the Cumberland Marshes as no substantial number of fish in this size range passed upstream into the Saskeram Marshes during the spawning run. Only a small percentage of white suckers caught during April - May were less than 40 cm (Fig. 40).

Walleye - Age and length frequencies for walleyes are presented only for 1983, since the sample size for 1984 (27 fish) was too small. The walleye sample for 1983 is representative of the spawning population. The majority of walleyes sampled in 1983 were between 6 and 8 years of age, with a mode of 7 years (Fig. 41). Female walleyes were similar in age to the males, but were considerably larger than the males. Most females were greater than 45 cm in length, while males were generally 42 cm or less.

It should be noted that males outnumbered the females in the 1983 spawning run (89 vs 19). The same situation applied to the 1984 spawning run which consisted of 28 fish; only 25 per cent were females.

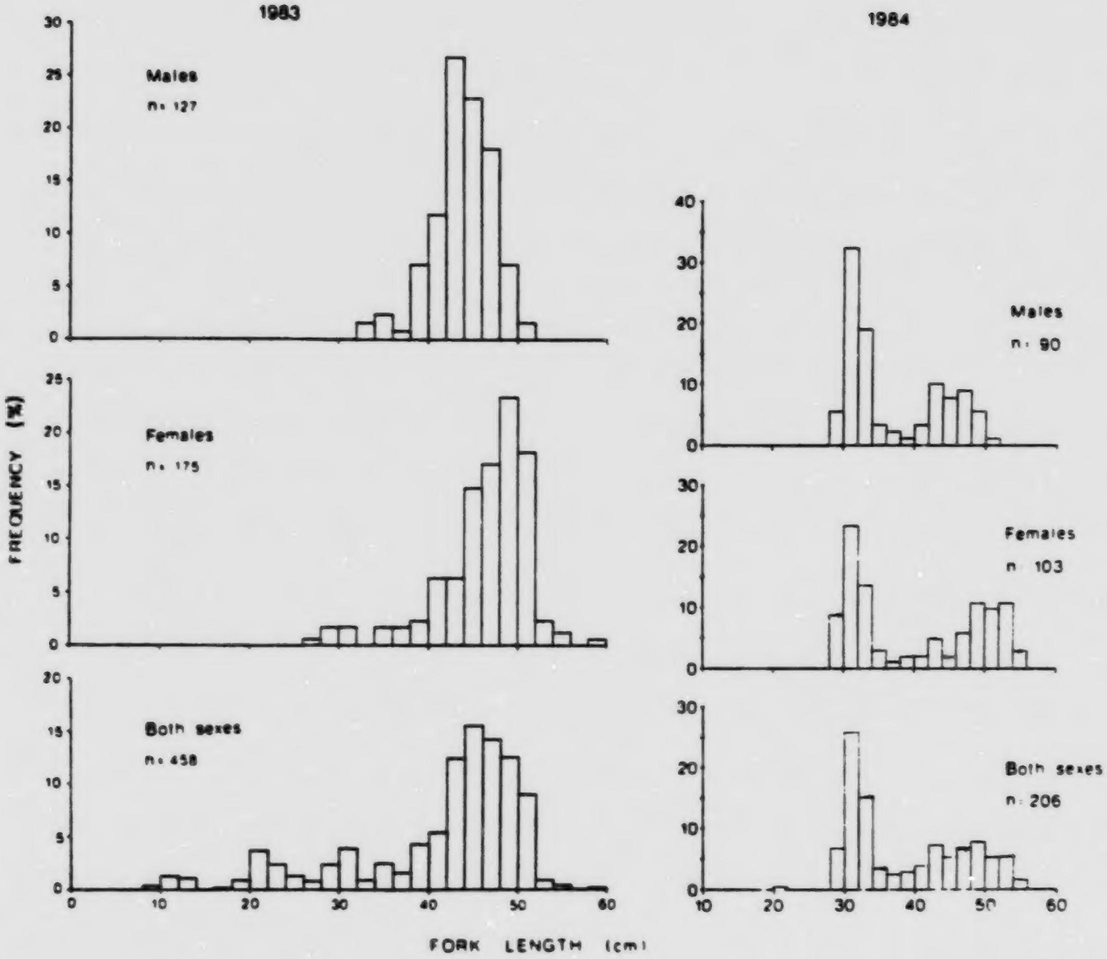

Fig. 38. Length frequency distribution of white suckers sampled from the Saskeram Marshes and at Bracken Dam during 1983 and 1984.

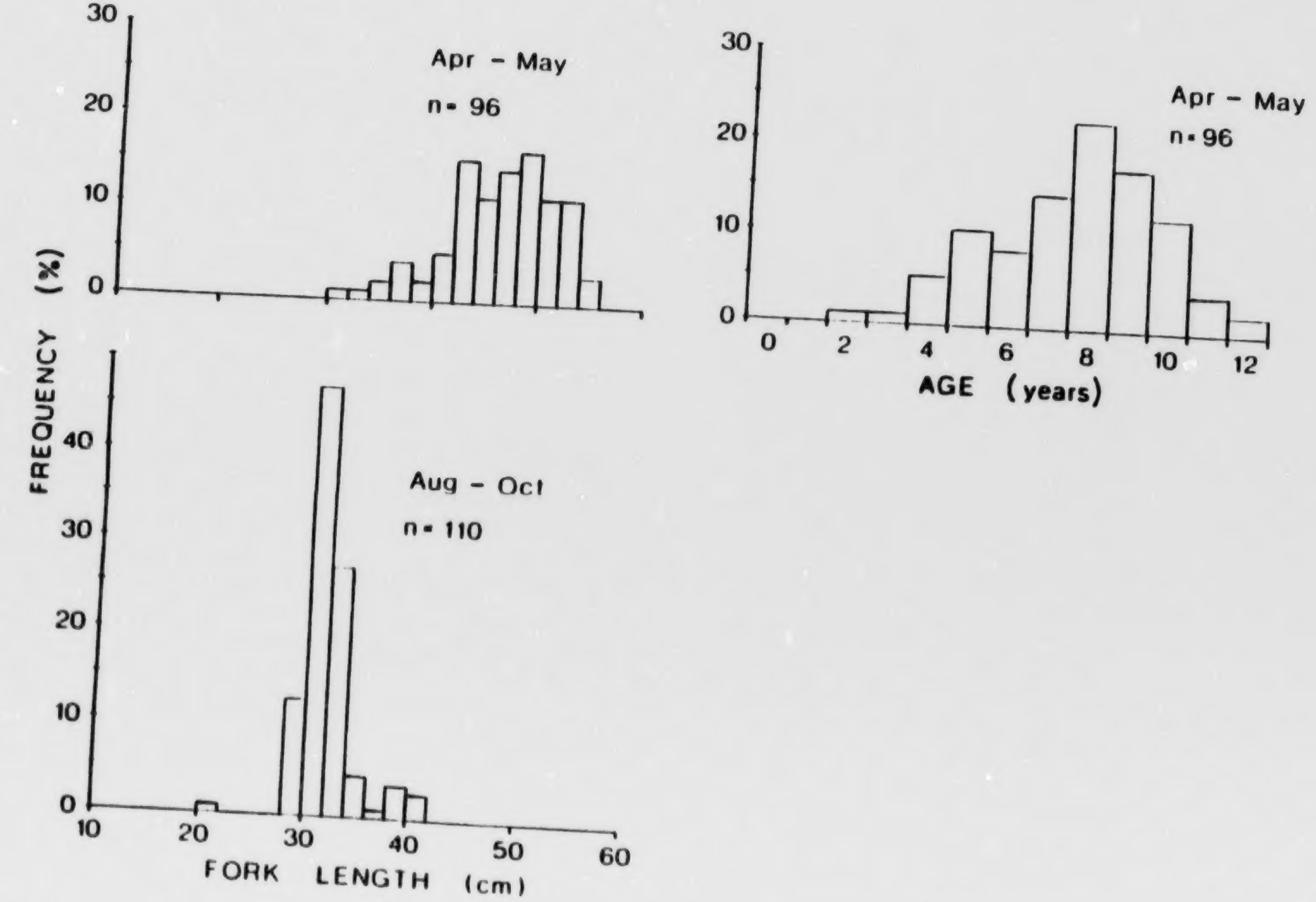

Fig. 39. Age and length frequency distributions of adult and spawning-run white suckers caught at Bracken Dam in April - May - 1984 and the length frequency distribution of juvenile white suckers which moved out of the Saskeram Marshes during August - October, 1984

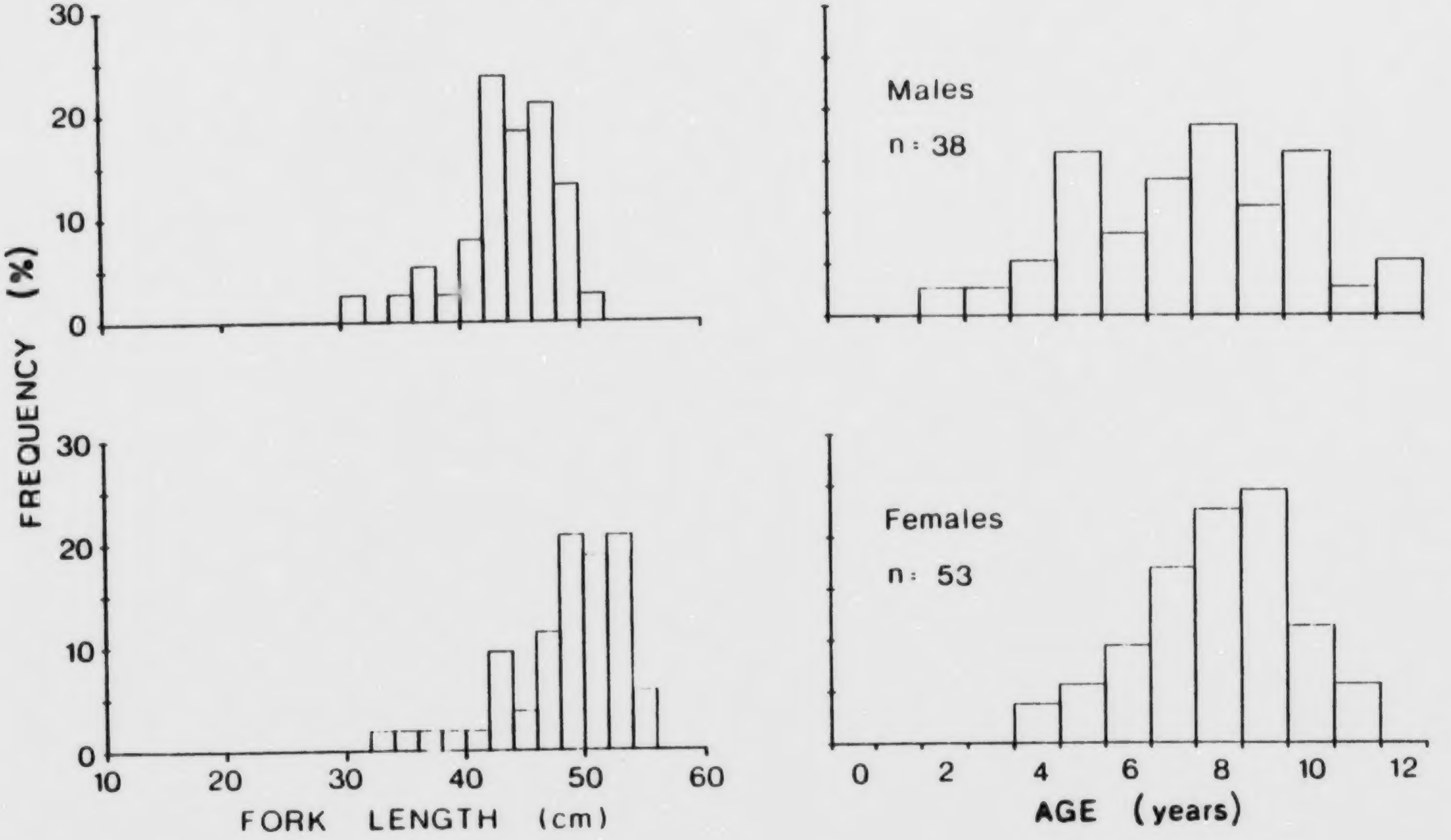

Fig. 40. Age and length frequency distributions of spawning-run and adult male and female white suckers caught at Bracken Dam during April - May, 1984.

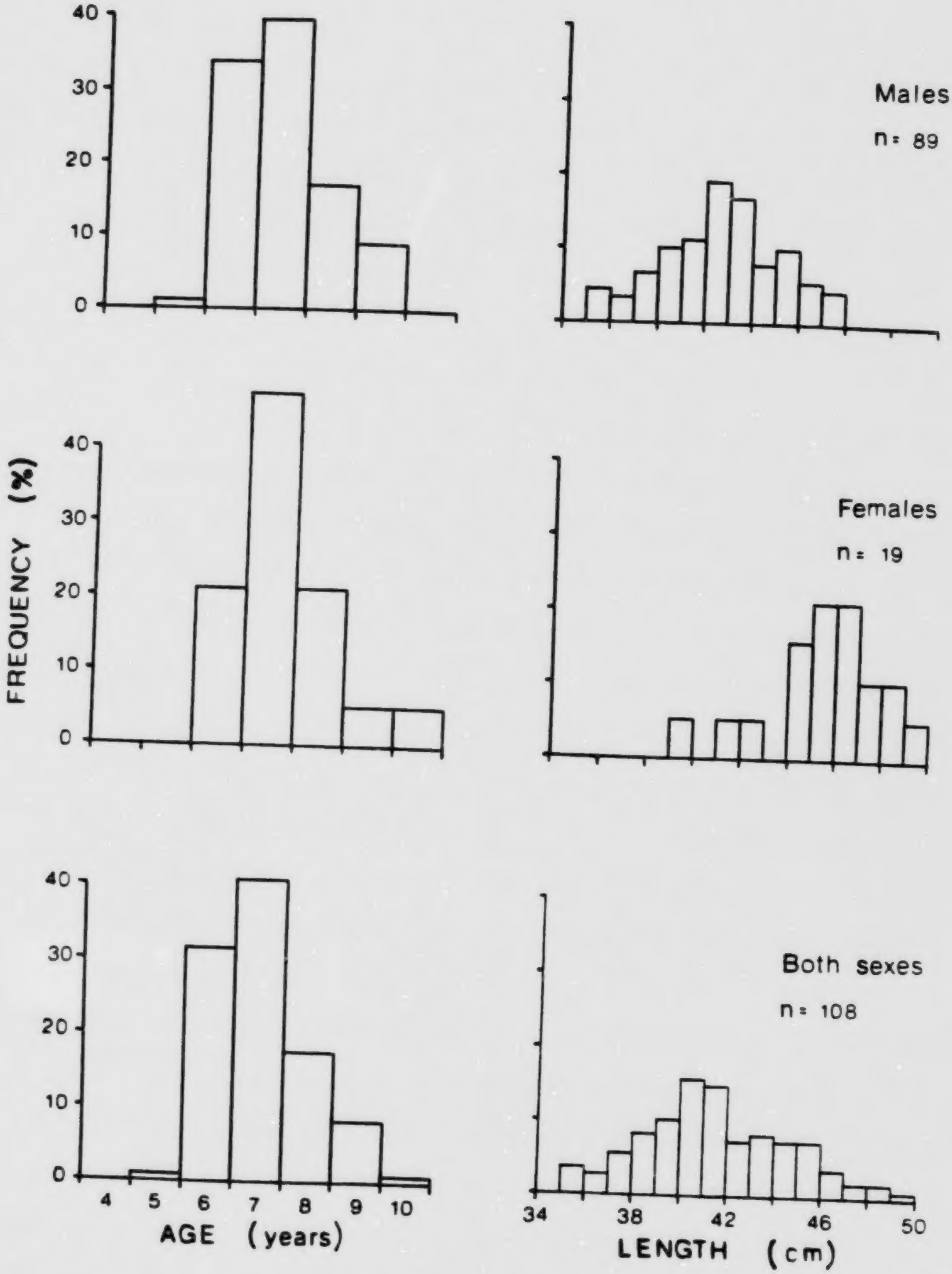

Fig. 41. Age and fork length frequency distributions of spawning run walleye caught at Bracken Dam in May, 1983.

Carp - Age and length information is presented on the 1983 spawning run of carp into the Saskeram Marshes. Although carp as old as 20 years were caught, the age distribution was mainly between 10 and 15 years (Fig. 42). The age distribution appeared to be bimodal with peaks at 11 and 13 years. This bimodality was also reflected in the length frequency distribution.

Growth/Condition

The following text presents a general overview of the growth and condition of fishes sampled from the Saskeram Marshes in 1983 and 1984. Growth is presented in terms of age specific lengths only; changes in weight with age followed the same pattern as changes in length. Summaries of detailed information on the mean fork lengths, weights and condition factors specific to age and to location and time (i.e. month) of sampling are presented for each species in Appendices XI through XXII. Data on incremental growth determined from tag recaptures among pike, white suckers and walleyes are listed in Appendices XXIII through XXV.

Northern pike - The growth of pike in 1984 appeared to be greater than in 1983 (Fig. 43). In the younger age groups (ages 0 to 3) pike caught in 1984 were about 70 mm longer than those in 1983 for a specific age. From age 3 to 6, this difference dropped to approximately 50 mm. Annual differences in the length of pike older than 6 years are due to small sample size (<2 fish per age group).

An examination of the growth data using Walford plots produced lines with similar slopes, but L_∞ for 1984 was about 50 mm higher than for 1983 (Fig. 44). In determining the regression lines, lengths at age 0 were omitted since the sampling of young-of-the-year pike in 1983, at

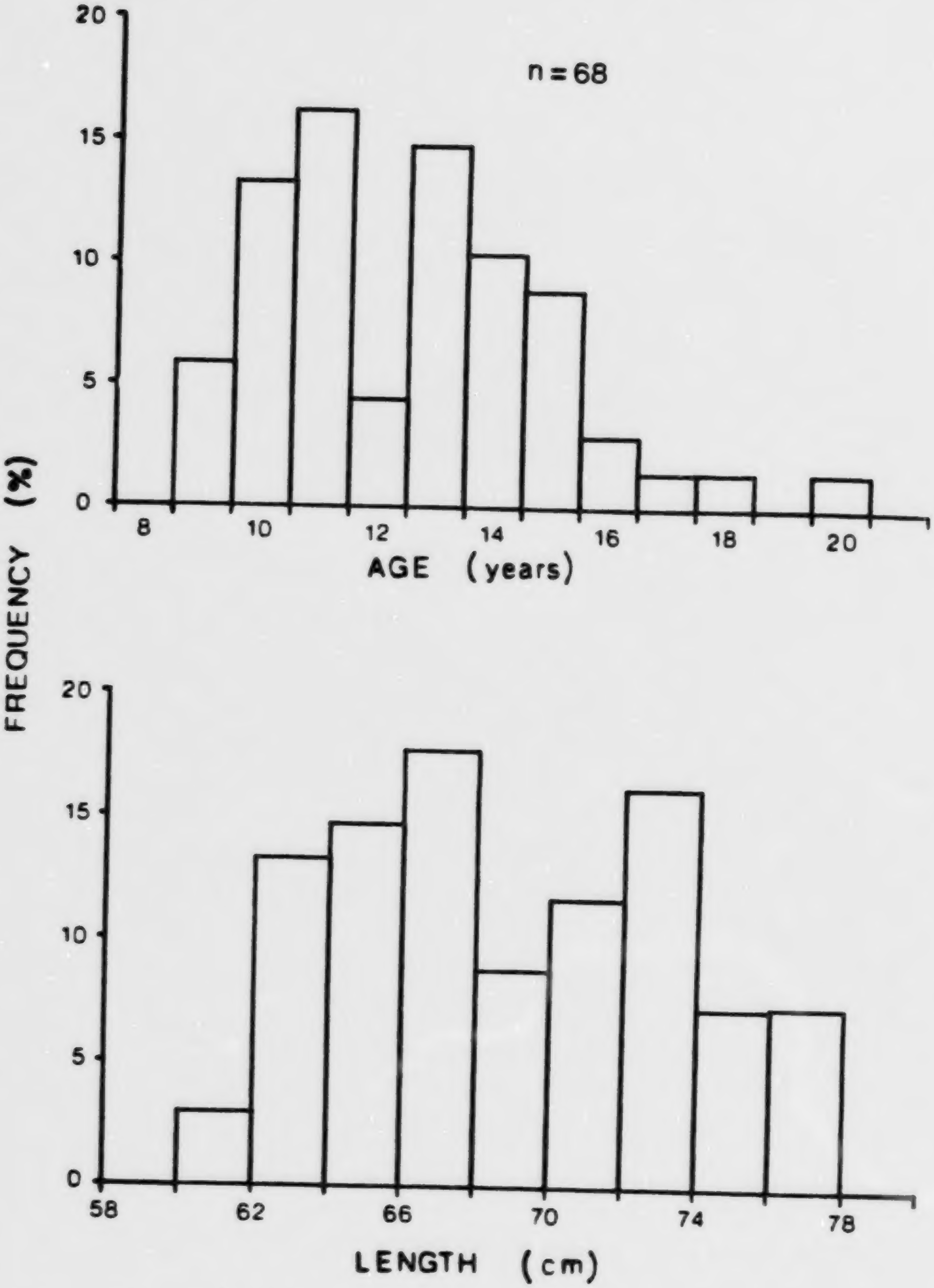

Fig. 42. Age and fork length frequency distributions of spawning run carp (sexes combined) caught at Bracken Dam in June, 1983.

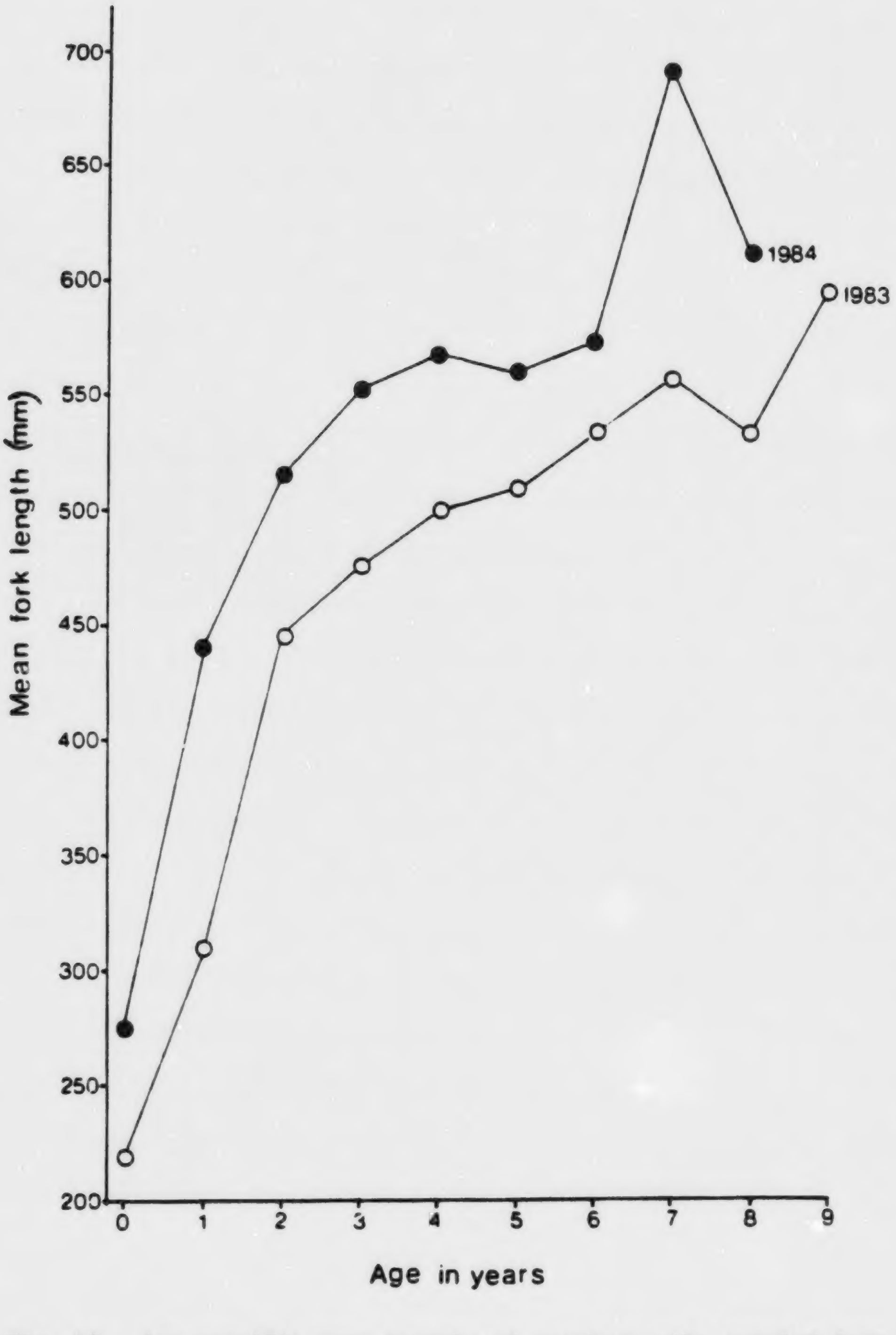

Fig. 43. Age specific mean lengths of northern pike sampled from the Saskeram Marshes and at Bracken Dam in 1983 and 1984.

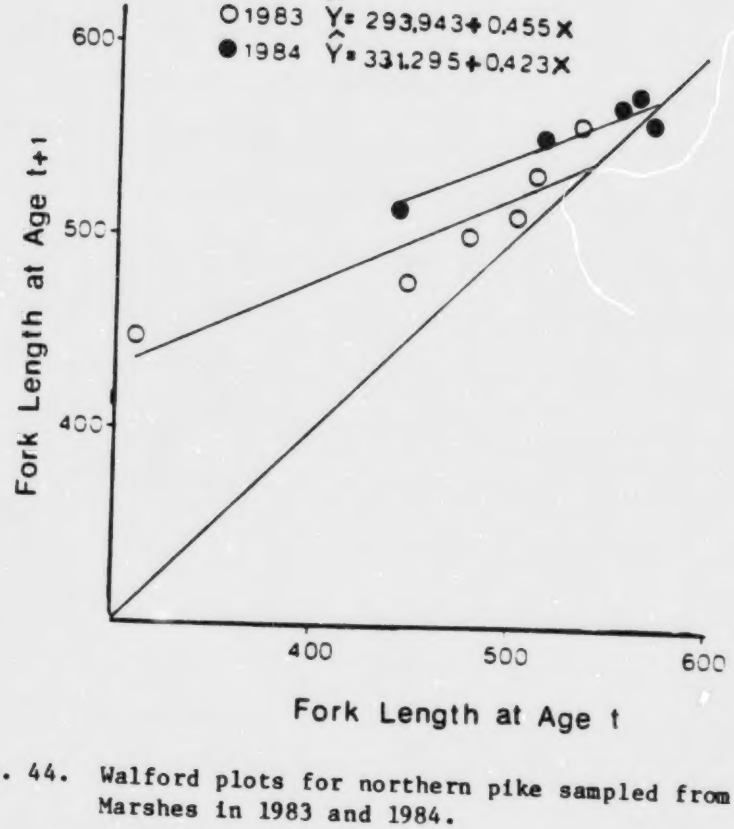

Fig. 44. Walford plots for northern pike sampled from the Saskeram Marshes in 1983 and 1984.

least in some instances, was biased toward capturing larger members of the cohort. The similarity in the regression line slopes suggests that growth rates in both years were the same, although the pike in 1984 achieved larger sizes because of the earlier spring breakup and longer growing season. In both years, female pike in most age groups tended to grow larger than the males (Fig. 45).

The above noted divergence in the size of pike in 1983 and 1984 also appeared in the young-of-the-year pike. Comparison of biweekly samples of young-of-the-year pike collected from July 1 to mid-December in 1983 and to early November in 1984, indicated a wide separation in growth (Fig. 46). In both years, growth stopped on approximately the same date (on or about October 1). However, in 1984 the young pike had attained a fork length of more than 30 cm by the end of the growing season as opposed to a length of just over 25 cm in 1983. Comparison of the growth rates of young-of-the-year pike in the two years using Walford plots indicated the growth rates were essentially the same in both years (Fig. 47). As was noted in the case of the adult pike, the larger size attained by the young-of-the-year pike in 1984 may also have been due to the increased length of the growing season.

Data on the length of pike at the time of tagging and subsequent recapture permitted an estimate of their incremental growth. Although limited, these data indicate that the younger age group pike (i.e. <age 4) put on greater growth than the older pike. Young pike added 1 to 2 mm of length per day while older pike appeared to achieve less than 1 mm per day (Appendix XXIII). These increments are based on the total elapsed time between tagging and recapture.

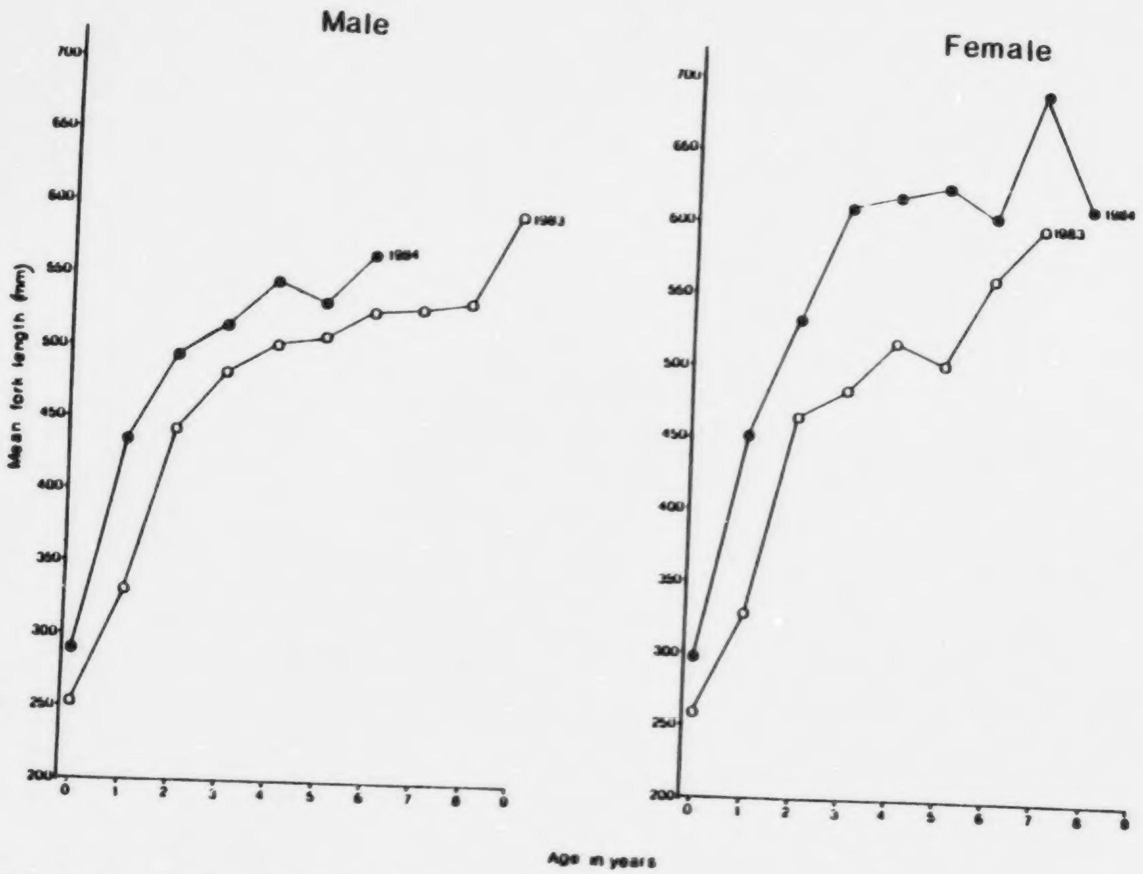

Fig. 45. Age specific mean lengths of male and female pike from the Saskeram Marshes in 1983 and 1984.

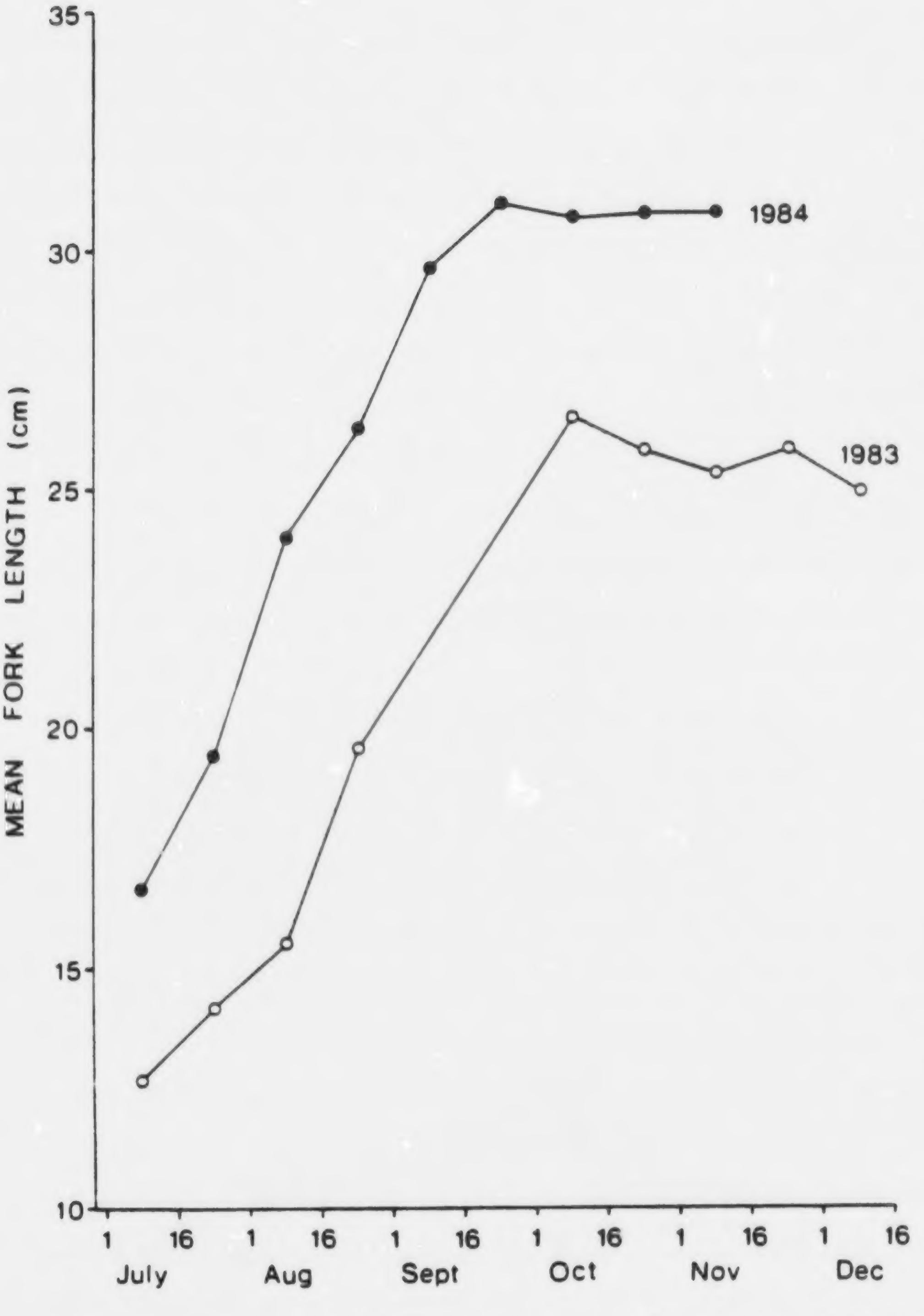

Fig. 46. Mean lengths of young-of-the-year pike from the Saskeram Marshes during biweekly periods from July through to December in 1983 and 1984.

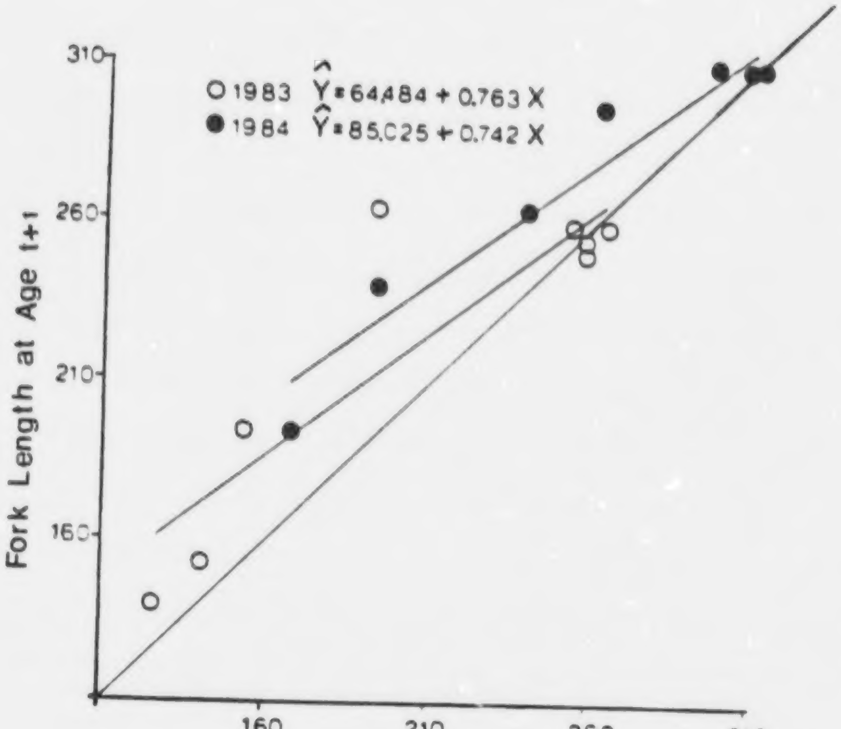

Fig. 47. Walford plots of young-of-the-year northern pike sampled from the Saskeram Marshes in 1983 and 1984.

Northern pike exhibited allometric growth at all ages; that is, condition factors were less than 3. In most cases, condition factors varied closely around 0.77 (Table 17). Although no gross seasonal trends were evident in condition factors, monthly means for 1983 samples, as reported in Appendix XVIIIa, showed higher condition factors in May and December. In May, a condition factor of 0.86 was found for female pike caught at Bracken Dam, while that for males was 0.83. This was due to the effect of sexual development. In June, following spawning, the condition factor of adult pike dropped to less than 0.75. In December, a condition factor of 0.86 was found for young-of-the-year pike. This high condition was probably a reflection of good growth attained by the young pike during the summer months. Condition factors for young pike (<age 1) sampled from the Saskeram and Cumberland marshes in August 1984 (Appendix XVIIIb) also reflected the good growth attained by young-of-the-year pike in 1984. No consistent trends in condition factors were evident in pike with a change in age (Appendices XI and XII).

Walleye - A comparison of age specific lengths of walleyes indicated no difference in growth between 1983 and 1984 (Fig. 48). However, as both samples were collected in the spring before the onset of active growth, the data essentially depict growth achieved in the previous years (1982 and 1983). The growing season in each of these years started around the same time; ice-breakup occurred shortly before May 1 in each year. The incremental growth of walleyes, based on the recovery of three tagged fish appeared to be about 1 mm per day or 3 mm per day based on a 100 day growing season (Appendix XXV). Condition factors of walleyes in 1983, although greater, did not appear to be significantly different from those in 1984 (Table 18).

Table 17. Seasonal and annual condition factors for northern pike from the Saskeram Marshes, 1983 and 1984.

	1983			1984		
	Sex			Sex		
Season	Male	Female	Both	Male	Female	Both
Spring	0.76	0.73	0.76	0.74	0.79	0.75
Summer	0.77	0.74	0.77	0.79	0.77	0.78
Fall	0.80	0.78	0.79	-	-	-
Annual	0.77	0.75	0.77	0.77	0.77	0.77

Table 18. Condition factors of spawning-run walleyes in the Saskeram Marshes in May, 1983 and 1984.

	Condition Factor	
Sex	1983	1984
Male	1.36	1.22
Female	1.30	1.34
Both	1.35	1.25

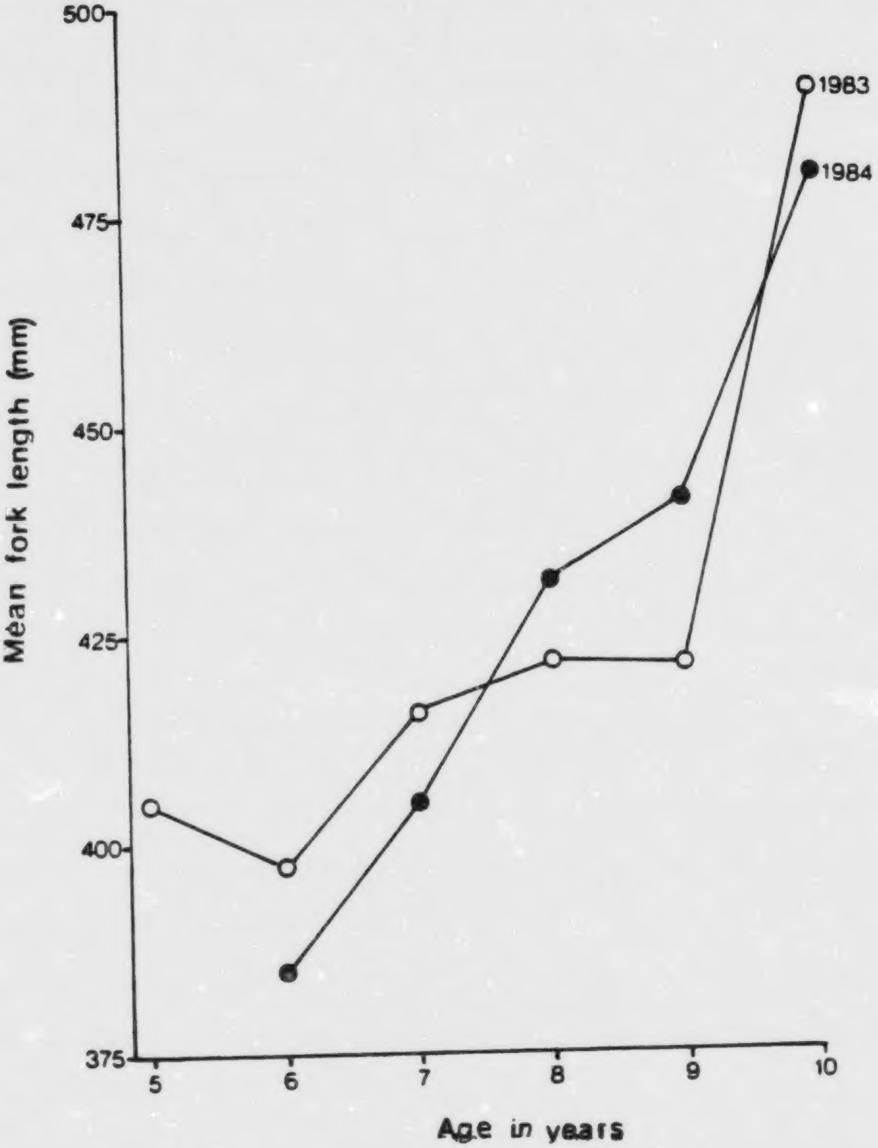

Fig. 48. Age specific mean lengths of walleyes caught at Bracken Dam in May, 1983 and 1984.

Carp - Plots of age specific lengths for carp in 1983 and 1984 suggested that there was little variation between growth rates in the two years (Fig. 49). Variations noted in the 1984 sample may be attributed to smaller sample sizes; 68 individuals were represented in the 1983 sample, whereas the 1984 sample contained only 24 fish. One tagged carp was recaptured 374 days after it was released. Its fork length at tagging and recapture was 72 and 75 cm, respectively. This represents an incremental growth rate of 0.8 mm per day.

Condition factors of carp in 1983 were substantially larger than in 1984 (Table 19). There was a tendency for condition factors to decrease with age (Appendix XVI). Condition factors in the younger fish (<age 10) suggested a more isometric growth pattern in the immature carp population.

White sucker and goldeye - A plot of age specific lengths of white suckers sampled during the spawning run in 1984 indicated very rapid growth within the younger age groups. More than half the growth of white suckers (up to approximately 30 cm) is attained during their first two years (Fig. 50). By age 7, when they reached a length of 47 cm, growth begins to attentuate and appears to level off around 50 cm. Incremental growth of white suckers, as determined from recaptured tagged fish, averaged about 0.4 mm per day (Appendix XXIV).

Goldeyes grew to a length of 20 cm by age 1 and reached a fork length of 32 cm by age 4 (Fig. 51).

Condition factors determined for both white suckers and goldeyes indicated allometric growth. In both species, the condition factor was higher for females than for males (Table 20).

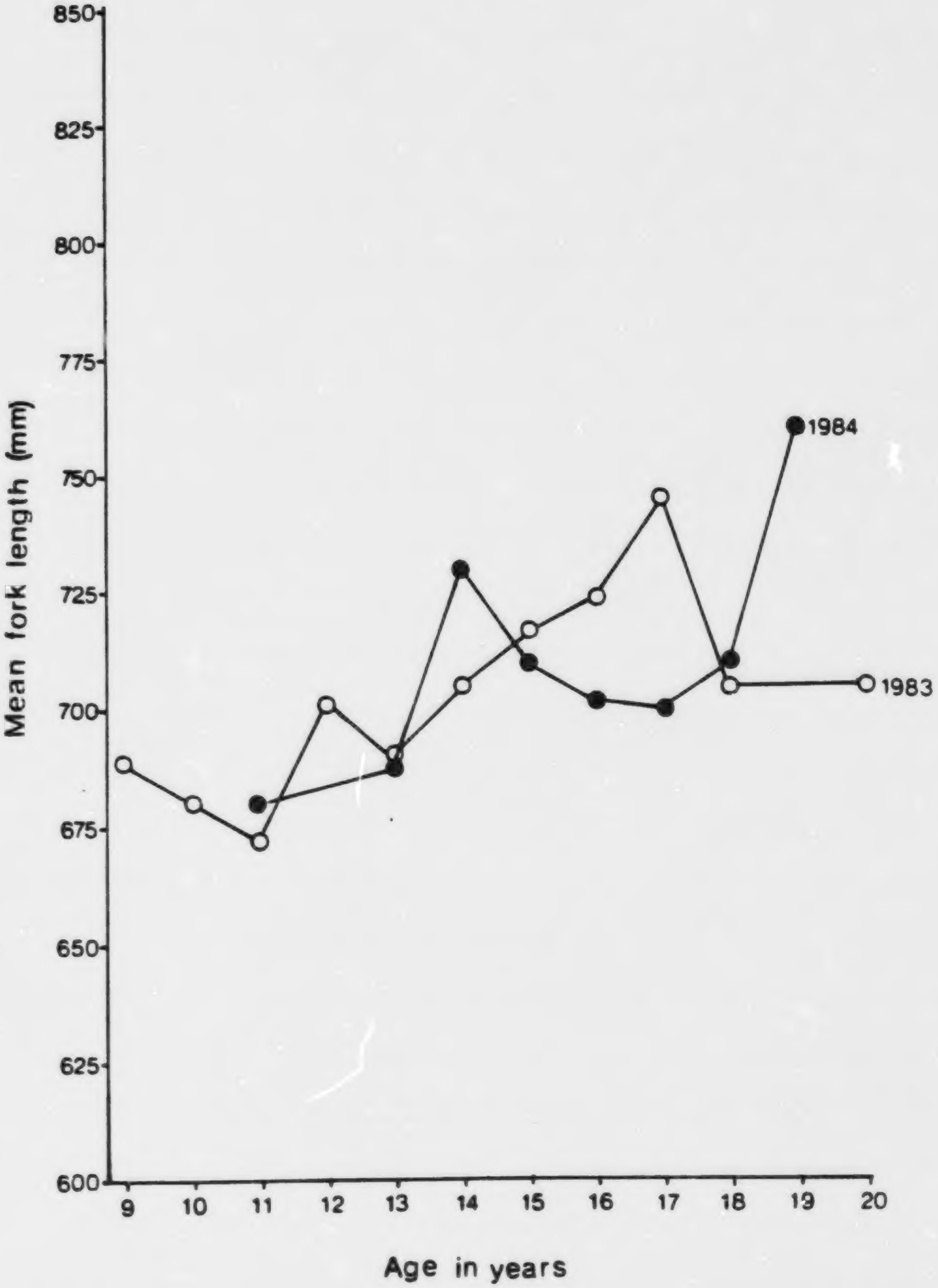

Fig. 49. Age specific mean lengths of carp caught at Bracken Dam in 1983 and 1984.

Table 19. Condition factors of spawning-run carp in the Saskeram Marshes in June, 1983 and May - June, 1984.

Sex	Condition Factor	
	1983	1984
Male	2.26	2.01
Female	2.39	1.88
Both	2.31	1.98

Table 20. Condition factors of Saskeram Marshes white suckers in April - May, 1984 and goldeye in September - October, 1984.

Sex	Condition Factor	
	White sucker	Goldeye
Male	1.53	1.03
Female	1.61	1.14
Both	1.56	1.03

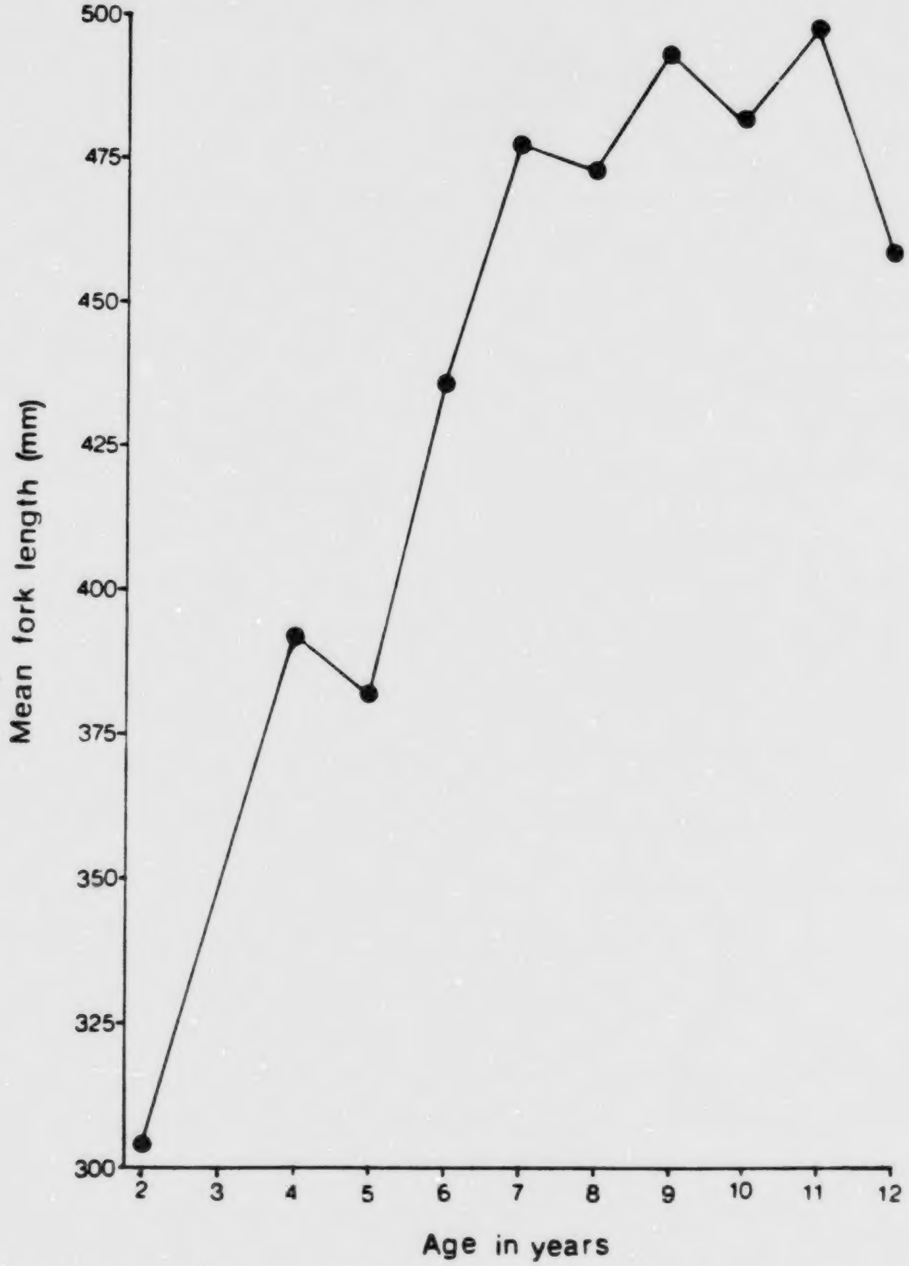

Fig. 50. Age specific mean lengths of white suckers caught at Bracken Dam in May, 1984.

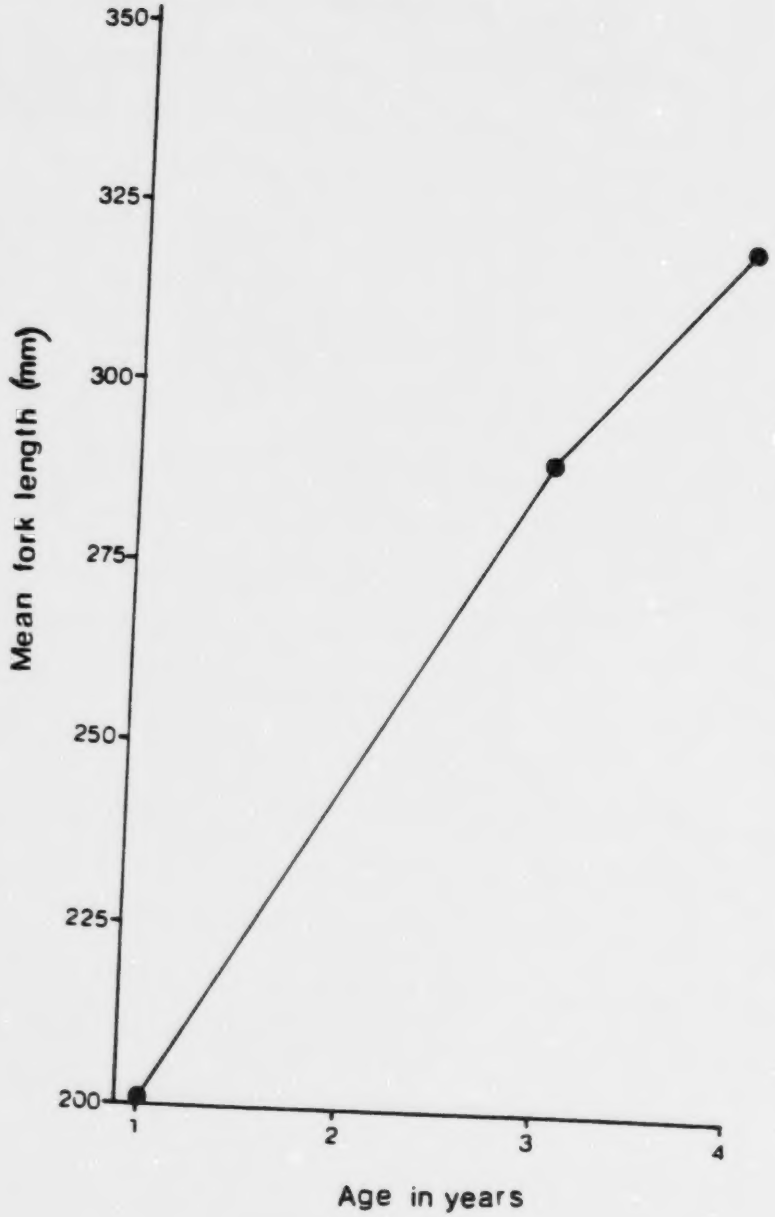

Fig. 51. Age specific mean lengths of goldeyes caught in September and October, 1984, while moving out of the Saskeram Marshes.

Sexual Maturity

The mean ages at sexual maturity using Abrasov's (1967) method, were determined for northern pike in 1983 and 1984 (Appendix XXVI). The ages of sexual maturity, based on data for both sexes combined, were less than two years; they were 1.83 and 1.09, respectively, in 1983 and 1984. The 1983 data suggested that the male pike matured at an earlier age than the females. The opposite was found in 1984. It is not known whether the greater growth experienced by pike in 1984 had any influence on the rate of sexual maturity in that year.

Survival/Mortality

Survival and mortality rates were determined using Robson and Chapman's (1961) catch curve method and the linear regression method developed by Lysack (1980). Survival and mortality rates in 1983 and 1984 could only be determined for pike and carp; no suckers were aged in 1983 and the 1984 sample of walleyes was too small to provide an adequate estimate. High annual mortality rates were determined for pike; they varied from 50 to 75 per cent, depending on the years and the estimator used (Table 21). Except for the 1984 Robson - Chapman estimate, the survival rates for pike were less than 40 per cent.

Walleyes, like pike, exhibited a high mortality and poor survival. The annual mortality rate of walleyes in 1983 ranged between 72 and 77 per cent (Table 22). Survival rates of white sucker were somewhat better than for walleyes; the annual survival for white suckers was approximately 45 per cent (Table 23).

Carp demonstrated very high survival rates in both 1983 and 1984. Except for the Robson - Chapman estimate in 1984, annual survival rate estimates for carp ranged between 50 and 64 per cent (Table 24).

Table 21. Mortality and survival rates of northern pike in 1983 and 1984 as estimated by the Robson-Chapman and regression methods.

Year/Method	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
1983					
Robson-Chapman	4-8	1.000	0.630	0.367 ± 0.033	-
Regression	4-8	1.386	0.750	0.250	0.935
1984					
Robson-Chapman	3-8	0.677	0.492	0.508 ± 0.050	-
Regression	3-8	1.006	0.632	0.368	0.869

Table 22. Walleye mortality and survival rates in 1983 as estimated by Robson-Chapman and regression methods.

Method	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
Robson-Chapman	8-10	1.260	0.717	0.282 ± 0.147	-
Regression	8-10	1.472	0.771	0.229	0.925

Table 23. White sucker mortality and survival rates in 1984 as estimated by Robson-Chapman and regression method.

Method	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
Robson-Chapman	9-12	0.820	0.560	0.440 ± 0.131	-
Regression	9-12	0.752	0.527	0.472	0.967

Table 24. Mortality and survival rates of carp in 1983 and 1984 as estimated by the Robson-Chapman and regression methods

Year/Method	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
1983					
Robson-Chapman	14-20	0.572	0.436	0.564 ± 0.158	-
Regression	14-20	0.451	0.364	0.636	0.848
1984					
Robson-Chapman	17-19	0.980	0.625	0.375 ± 0.337	-
Regression	17-19	0.693	0.498	0.501	0.866

This high survival also coincides with their apparent greater longevity; carp as old as 20 years were represented in our samples.

Feeding Habits

The only fish feeding habits considered in this study were those of pike. White suckers, the only other species encountered in appreciable numbers, were not considered since their stomach contents cannot be identified without detailed microscopic examination. Macroscopic inspections were made of stomach contents from all pike autopsied in 1983 and 1984. Invertebrate food items were mostly identified to Order, and to Family in a few cases. Wherever possible, fish found in the stomach contents were identified to the species level. Results of the stomach content examinations are presented in terms of percentage frequency occurrence of each food item, based only on those specimens which contained food. Results are presented separately for adult and juvenile pike in each year; juvenile pike are primarily young-of-the-year pike. Stomach contents of adult pike in 1983 and juvenile pike in both 1983 and 1984 are presented on a monthly basis.

Adult pike - In 1983, 695 adult pike were examined for stomach content (Table 25). Since all of these fish were captured upstream of Bracken Dam, the food items found would be indicative of feeding in the Saskeram Marshes or the lower Birch River. Invertebrates formed the major portion of the diet of pike in May; all of the stomachs with food contained invertebrates. The most important items were leeches (Hirudinea) and amphipods, followed by fish and dragonfly nymphs (Odonata). Frogs and a small mammal, probably a mouse, were also observed in several stomachs. In June, fish became more prominent in the

Table 25. The stomach contents of adult pike in the Saskeram Marshes in 1983. The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	May	June	July	Total
Number examined	249	432	14	695
Empty stomachs	94	102	5	201
Number containing food	155	330	9	494
Unidentified matter	17.4 (27)	10.0 (33)	22.2 (2)	12.6 (62)
Fish	18.1 (28)	60.9 (201)	77.8 (7)	47.8 (236)
Digested fish	7.7 (12)	28.5 (94)		21.5 (106)
Brook stickleback	10.3 (16)	32.1 (106)	77.7 (7)	26.1 (129)
Fathead minnow		0.3 (1)		0.2 (1)
Invertebrates	100.0 (155)	58.2 (192)	22.2 (2)	72.3 (349)
Amphipoda	35.5 (55)	17.6 (58)	11.1 (1)	23.1 (114)
Odonata	17.4 (27)	17.9 (59)		17.4 (86)
Plecoptera	1.3 (2)			0.4 (2)
Insect remains	0.6 (1)			0.2 (1)
Hirudinea	50.3 (78)	22.7 (75)		31.0 (153)
Pelecypoda			11.1 (1)	0.2 (1)
Other	1.9 (3)	0.3 (1)		0.8 (4)
Frog	1.3 (2)			0.4 (2)
Mammal (mouse)	0.6 (1)			0.2 (1)
Bird		0.3 (1)		0.2 (1)

diet; 61 percent of the food ingested by pike was fish. The most commonly consumed fish species was brook (five-spine) stickleback. Invertebrates, although still prominent in the stomach contents, did not appear to be as important in the diet as they were in May. The adult pike did, however, continue to select leeches, amphipods and dragonflies. A young coot (Fulica americana) was noted in one pike. Only 14 fish were examined during July and 11 of these had injested food. Despite the small sample size, the data indicate a further shift to a predominant diet of fish (sticklebacks).

In 1984, the stomach contents of 377 adult pike were examined over the field seasons (Table 26). Many of these fish were sampled from the spawning run. This accounts for the high frequency of empty stomachs (71%) observed in the sample; pike do not actively feed during their spawning period. Because of this bias, the 1984 sample is not completely comparable to the 1983 sample. Despite this bias, leeches, amphipods and dragonfly nymphs were well represented among the invertebrate organisms selected in 1984, although they were not as important as in 1983. Fish appeared to be of greater importance in the diet of adult pike in 1984. Pike also selected a greater variety of fish. Young-of-the-year pike were more prevalent (29%) than sticklebacks (15%). A portion of the adult pike sampled were unusually large pike which, it is believed, were introduced from the Cumberland Marshes during the autumn. These pike were, on the whole, larger than those pike observed entering the Saskeram Marshes during the spring spawning run at Bracken Dam. These larger pike may account for the observed predation on young pike. A young grebe and a mouse were also noted in two pike.

Table 26. The stomach contents of adult pike in the Saskeram Marshes in 1984. The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	All Months
Number examined	377
Empty stomachs	234
Number containing food	143
	%
Unidentified matter	28 (40)
Fish	69 (98)
Digested fish	20 (28)
Brook stickleback	15 (21)
Fathead minnow	3 (5)
Spottail shiner	1 (1)
White sucker (Y.O.Y.)	2 (2)
Pike (Y.O.Y.)	29 (41)
Invertebrates	25 (36)
Amphipoda	3 (5)
Coleoptera	1 (1)
Odonata	5 (7)
Hirudinea	10 (14)
Pelecypoda	4 (6)
Gastropoda	2 (2)
Other	1 (2)
Bird (Grebe)	1 (1)
Mammal (mouse)	1 (1)

YOY pike - A total of 821 young-of-the-year pike were examined for stomach content in 1983; 54 per cent (440) of these fish contained food (Table 27). Samples taken during July and August showed a high selectivity for invertebrate food items, although fish were also relatively important in the diet. During July and August, invertebrates were found in at least 65 per cent of all stomachs containing food. The most common group of invertebrates represented in the gut content was amphipods. Odonate nymphs, and particularly damselflies (Zygoptera) were the next most dominant invertebrate group found in the July and August samples. Sticklebacks were the most prominent forage fish taken by the pike. Young-of-the-year pike appeared to feed heavily during July and August; approximately two-thirds of all samples examined in these months had fed. Even though a small sample (30 fish) was examined to September and most of these did not contain food in their gut, the results suggested that invertebrates were still an important food item for young pike. Two of the four specimens that had fed in September contained insect remains. Invertebrates, especially amphipods, continued to be an important diet item through October and November. Forage fish, primarily sticklebacks, increased in occurrence. By December, 90 per cent of the diet was sticklebacks. Sticklebacks appeared to form the total diet of young-of-the-year pike in January 1984.

In 1984, a smaller proportion of the young-of-the-year pike had fed; 43 per cent of the 731 stomachs examined contained food. The 1984 data were similar in some respects to the 1983 data (Table 28). For example, sticklebacks were prominent in the July sample and amphipods were the most commonly occurring group among the invertebrates. Also, two-thirds of the samples examined in July and August contained food.

Table 27. The stomach contents of juvenile pike in the Saskeram Marshes in 1983 and 1984 (January). The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	July	August	September	October	November	December	January 1984	Total
Number examined	149	71	30	137	173	210	51	821
Empty stomachs	62	24	26	77	96	78	18	381
Number containing food	87	47	4	60	77	132	33	440
	%	%	%	%	%	%	%	%
Unidentified matter	11.4 (10)	8.5 (4)	25.0 (1)	6.6 (4)	2.5 (2)	4.5 (6)		6.1 (27)
Fish	47.1 (41)	36.1 (17)	25.0 (1)	56.6 (34)	42.8 (33)	93.1 (123)	100.0 (33)	64.0 (282)
Digested fish	5.7 (5)	8.5 (4)	25.0 (1)	11.6 (7)	3.8 (3)	3.0 (4)	30.3 (10)	7.7 (34)
Brook stickleback	34.4 (30)	19.1 (9)		38.3 (23)	37.6 (29)	90.1 (119)	66.6 (22)	52.7 (232)
Cyprinid	2.2 (2)				1.2 (1)			0.6 (3)
Fathead minnow	4.4 (4)	4.2 (2)		3.3 (2)			3.0 (1)	2.0 (9)
Spottail shiner				1.6 (1)				0.2 (1)
White Sucker (Y.O.Y.)		4.2 (2)						0.4 (2)
Pike (Y.O.Y)				1.6 (1)				0.2 (1)
Invertebrates	65.5 (57)	74.4 (35)	50.0 (2)	41.6 (25)	58.4 (45)	5.3 (7)		38.8 (171)
Amphipoda	41.3 (36)	34.0 (16)		23.3 (14)	50.6 (39)	5.3 (7)		25.4 (112)
Coleoptera	2.2 (2)	4.2 (2)						0.9 (4)
Dytiscidae	1.1 (1)							0.2 (1)
Zygoptera	13.7 (12)	10.6 (5)		1.6 (1)	3.8 (3)			4.7 (21)
Odonata	2.2 (2)	6.3 (3)		13.3 (8)	2.5 (2)			3.4 (15)
Ephemeroptera					1.2 (1)			0.2 (1)
Plecoptera		2.1 (1)						0.2 (1)
Hemiptera		2.1 (1)						0.2 (1)
Corixidae		2.1 (1)						0.2 (1)
Notonectidae				1.6 (1)				0.2 (1)
Chironomidae	1.1 (1)							0.2 (1)
Hirudinea	2.2 (2)	10.6 (5)						1.5 (7)
Copepoda	1.1 (1)							0.2 (1)
Insect remains		2.1 (1)	50.0 (2)	1.6 (1)				0.9 (4)
Other	2.2 (2)			1.6 (1)				0.9 (4)
Frog tadpole	2.2 (2)							0.4 (2)
Plant matter				1.6 (1)	1.2 (1)			0.4 (2)

Table 28. The stomach contents of juvenile pike in the Saskeram Marshes in 1984. The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	June	July	August	September	October	Total
Number examined	1	113	174	242	201	731
Empty stomachs	1	37	60	151	168	417
Number containing food		76	114	91	33	314
Unidentified matter		%	%	%	%	%
		30 (23)	46 (53)	33 (30)	6 (2)	34 (108)
Fish		68 (52)	48 (55)	58 (53)	55 (18)	57 (178)
Digested fish		7 (5)	14 (16)	33 (30)	30 (10)	19 (61)
Brook stickleback		42 (32)	12 (14)	1 (1)	15 (5)	17 (52)
Fathead minnow		20 (15)	20 (23)	22 (20)		18 (58)
Spottail shiner			2 (2)	1 (1)	6 (2)	2 (5)
Pike (Y.O.Y.)				1 (1)	3 (1)	(2)
Invertebrates		28 (21)	23 (26)	11 (10)	45 (15)	23 (72)
Amphipoda		16 (12)	15 (17)	10 (9)	39 (13)	16 (51)
Coleoptera			1 (1)			(1)
Odonata			(1)			(1)
Hemiptera		3 (2)				(2)
Hirudinea		1 (1)	2 (2)			1 (3)
Pelecypoda			2 (2)		3 (1)	1 (3)
Crustacea (Ostracoda)		8 (6)	3 (3)	1 (1)		3 (10)
Insect remains					3 (1)	(1)
Other						
Plant matter					3 (1)	(1)

The 1984 results however, differed in several respects from the 1983 data. Firstly, fish were the most frequently occurring diet item in each month in 1984. In 1983, fish did not become a major component of the diet until October. Except in October, invertebrates in 1984 did not occur in more than 30 per cent of the fish. This contrasts sharply with the 1983 results, where invertebrates made a significant contribution to the pike's diet throughout the ice-free period. Finally, the fathead minnow which was a very minor diet feature (2%) in 1983 was as important in the 1984 diet list as the stickleback.

HABITAT CHARACTERISTICS

No special efforts were made to describe and inventory fish habitat conditions within the Saskeram Marshes or contiguous waters during the openwater period. Because of limitations in manpower and access, it was impossible to follow adult fish movements into the marshes and document specific spawning habitats or areas occupied by newly hatched fish. Observations on spawning and other habitat conditions were based principally on extrapolations from similar fisheries studies. Similarly, it was not possible to quantify the abundance or availability of fish food organisms. Such information was limited to casual observations on the concentrations of invertebrate organisms caught in some nets[1] and to notes on the densities of forage fish in Beamish net catches in the Saskeram Lake area and in our traps on Bracken Dam.

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[1] Samples of invertebrates caught in drift nets set immediately upstream of Bracken Dam during the suspected periods for fry drift in 1983 and 1984, were submitted to the Manitoba Museum of Man and Nature. These samples contained a wide variety of invertebrate groups, but did not generally reflect the community of larger invertebrates present in the Saskeram Marshes. This information for 1983 and 1984 is on file at the Manitoba Museum of Man and Nature.

The two habitat characteristics measured with most consistency in this study were water temperatures and dissolved oxygen. The latter parameter was measured on frequent occasions, particularly in 1983 when a summerkill of pike was recorded in lower Birch River. The measurement of winter dissolved oxygen concentrations throughout the Saskeram Marshes, during the course of this study was limited to at least twice each winter.

Concurrently, some gill netting and visual observations on fish survival in the oxygen testing areas were made. Because of the limited winter oxygen sampling during this study and the relevance of winterkill situations to the study objectives, observations made on winter oxygen levels and fish survival in the Saskeram Marshes by other investigators have been incorporated in this report.

The following sections include the spawning and fish nursery habitat conditions of the Saskeram Marshes, some observations on fish food resources in the marshes, and the importance of temperature and oxygen to resident fish.

Spawning and Nursery Habitat

In terms of the large fish species, the Saskeram Marshes are best suited to marsh spawning species such as pike, goldeye and carp. Walleyes and suckers, which generally prefer streams with hard spawning substrates and moderately fast moving water to transport the newly hatched fry downstream are less suited to spawning in marshy conditions. Walleyes, however, will spawn in marshy areas where there are dense mats of flooded vegetation and moving water (Priegal 1970). Based on our observations of young fishes caught in the lower reaches of the marshes and at Bracken Dam, the Saskeram Marshes are primarily pike spawning habitat. This was the only species for which large numbers of young-of-the-year fish were recorded in and leaving the Saskeram Marshes. Only occasional catches of young-of-the-year white suckers were made. Young-of-the-year or juvenile walleyes, goldeyes, yellow perch and carp were very rarely observed in the marshes. The rarity of the young of these species in our catches, however, does not necessarily preclude the possibility that suitable spawning conditions for the species do exist in the Saskeram Marshes. If walleyes, goldeyes, carp, etc. do find suitable spawning habitats in the marshes, other circumstances may prevail which may limit or negate their further usage of the area. For example, conditions which highly favour pike production may create a high level of predation and interspecific competition on other species. The following habitat evaluation of the Saskeram Marshes is therefore directed principally to the area's utilization by pike.

The environmental or habitat requirements of northern pike have been well documented in numerous studies throughout North America and Europe. Many of these studies have been reviewed and used by Inskip (1982) to develop a Habitat Suitability Index (HSI) model for pike. The HSI model permits a quantitative assessment of a species habitat requirments. Information was not collected for all habitat parameters required in the pike HSI model. The model does, however, provide a useful format for evaluating the utility of the Saskeram Marshes as pike habitat. According to Inskip (1982), the habitat requirements of pike may be categorized in four stages. These are: spawning/embryo, fry, juvenile and adult. Since it has already been demonstrated that many spawning pike entering the Saskeram Marshes left within 30 to 40 days, the habitat conditions of principal importance are those related to spawning and the early life history stages of pike. It should be noted that Inskip (1982) presents HSI models for both lacustrine and riverine conditions. Seven habitat variables are common to both models, but the riverine model has an additional two variables which deal with stream features such as backwater areas and gradient. The following considerations are limited to features of the lacustrine HSI model and may be generalized in some instances because of the lack of information. A detailed description of the habitat variables applicable to the lacustrine HSI model is presented in Appendix XXVII.

Of the seven habitat variables, variables 3 to 7 do not appear to be limiting in the Saskeram Marshes. For example, the ratio of midsummer area with emergent and submerged aquatic plants to the total area is probably near optimum, especially if it is considered that many of the adult pike move out of the marshes by midsummer. Optimum temperature, pH and frost-free conditions reported by Inskip (1982) exist in Saskeram Marsh. Except for possibly the Elm Creek area, TDS concentrations are also at or near the optimum. The two most crucial habitat variables in Saskeram Marsh are the availability and type of spawning habitat and the variation in water levels during the incubation and early fry stages of pike.

According to Inskip (1982), prime spawning habitat for northern pike consists of flooded sedge or grass meadows, where most of the bottom (>80%) is obscured by a thick, but loosely compacted mat of vegetation about 15 cm above the substrate. Such areas are ideal for pike spawning, since they allow for good water circulation around the eggs and fry. Marsh vegetation such as reeds (Phragmites) or bullrushes (Scirpus) are less suited for pike spawning because they do not provide the same density of substrate coverage. This allows the eggs and fry to fall into the muck bottom. Large expanses of grasses and sedges are distributed along the east and south sides of Saskeram Lake (Cross 1982). According to information from a thematic plot of the Saskeram Lake area made from a June 26, 1981 Landsat satellite image (L. Bowles, unpublished data) and a contour map prepared by Ducks Unlimited, these sedge and grass areas are found between the 260.0 m (853 feet or FSL) and 259.5 m (851.5 feet) contours. The 259.4 m (851.0 feet) contour equates approximately with the fringe of Phragmites around Saskeram Lake. The central or deeper portion of Saskeram Lake consists primarily of bullrushes. Pike undoubtedly spawn throughout most of the Saskeram Marshes, but the greatest spawning success is probably achieved in the grass sedge meadows found in the Saskeram Lake area between the 260.0 and 259.5 m contours. Under these conditions, it is doubtful that the availability of spawning habitat relative to summer habitat is a limiting factor.

The most important consideration in the suitability of the Saskeram Marshes as pike habitat therefore appears to be drops in water level during the embryo and yolk-sac fry stages. Since the fish at this time are immobile and since spawning occurs in shallow water, drops in water level will expose the eggs or fry to dessication. Since the physical relief in the Saskeram Marshes is extremely low, even small drops in water levels may result in significant pike mortality. Figure 52 shows the stage-area curve for Saskeram Lake. The reductions in the

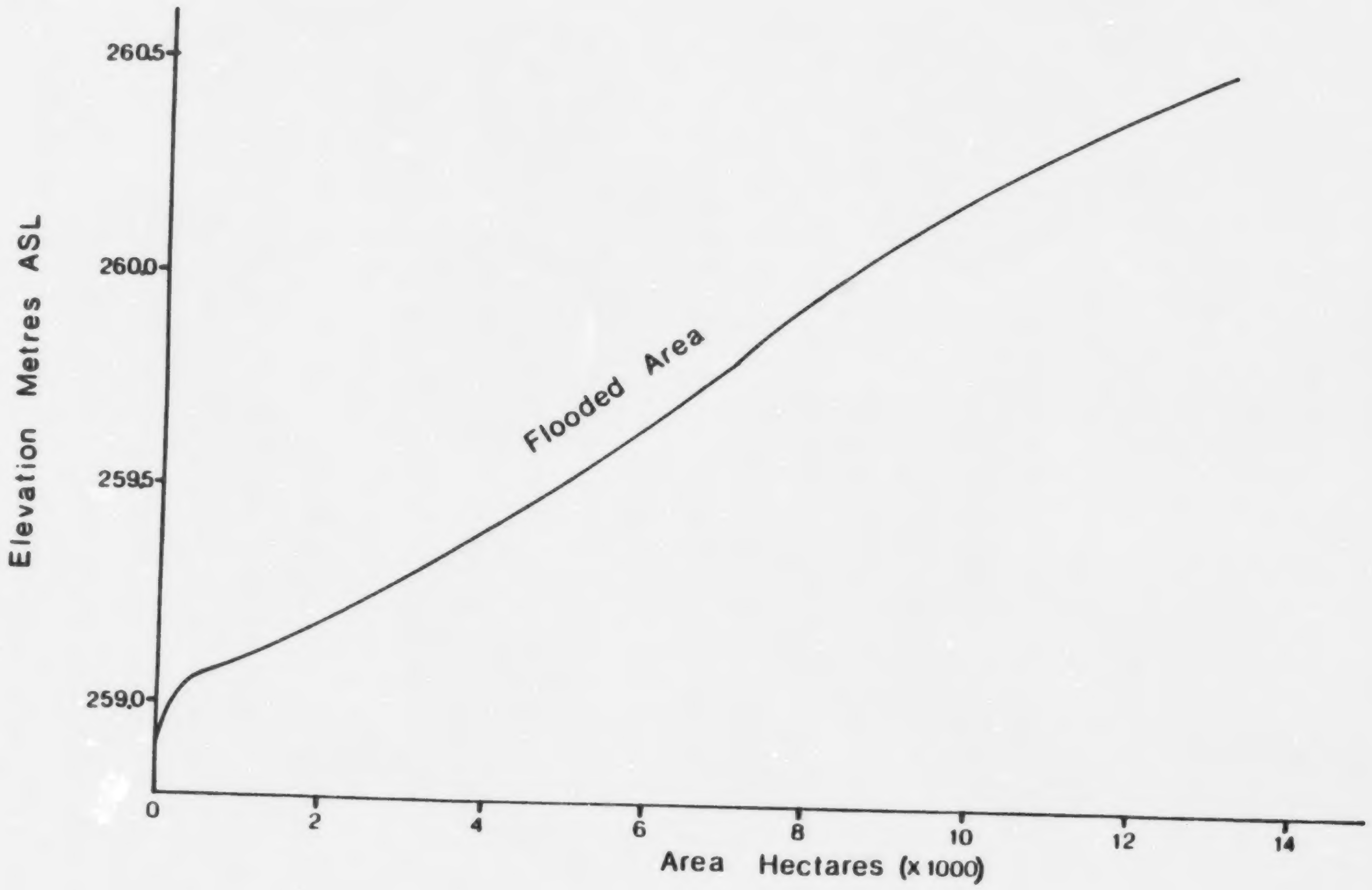

Fig. 52. Stage - area curve for Saskeram Lake. Data from Ducks Unlimited Canada.

amounts of potential pike spawning habitat for various water elevations on Saskeram Lake may be extrapolated from this stage-area curve. For example, for a 0.45 m decrease in elevation from FSL, there is almost a 40 per cent reduction in flooded area (Table 29). The effect of this decrease on pike eggs and fry may be considerably greater than a 40 per cent increase in mortality, because the area dewatered may contain the bulk of eggs deposited by pike.

To further assess the potential effects of water level changes on pike spawning success in the Saskeram Marshes, daily water levels during the surmised pike spawning and hatching period were plotted for the years 1981 - 1984 (Fig. 53). These years were selected because we have some information on pike use of the marshes. Although the water levels were recorded on the upstream side of Bracken Dam, they are believed to closely approximate variations in levels throughout the Saskeram Lake area. Spring water levels which prevailed during 1983 and 1984, fluctuated relatively little and were mostly above the 259.69 m (852 feet) contour. These levels not only provided stable conditions for spawning success, but also allowed pike into optimum spawning areas. The drop of about 0.2 m from May 2 to May 5, 1984, may or may not have exerted a mortality among pike eggs and fry. This drop occurred shortly after a snowstorm and unseasonably cold weather curtailed the pike spawning run into the Saskeram Marshes. It is not known whether the pike had spawned before or after the cold snap and the ensuing water level drop. It is believed, nevertheless, that the water level change had a minimal effect on mortality since levels did not drop below the 259.69 m contour and even rose appreciably during early June when the pike fry would have been leaving the spawning areas for deeper water.

Table 29. Effect of water level changes in Saskeram Lake on the availability of potential spawning habitat for northern pike. FLooded areas extrapolated from the Stage-Area curve (Fig. 52) developed by Ducks Unlimited.

Water Elevation - m ASL	Flooded Area - ha	Decrease in Water Area - ha
259.99 (853.0')*	8336	-
259.84 (852.5')	6880	1456
259.69 (852.0')	6333	2003
259.54 (851.5')	5180	3156
259.38 (851.0')	3905	4431
259.23 (850.5')	2590	5746

* Full supply level

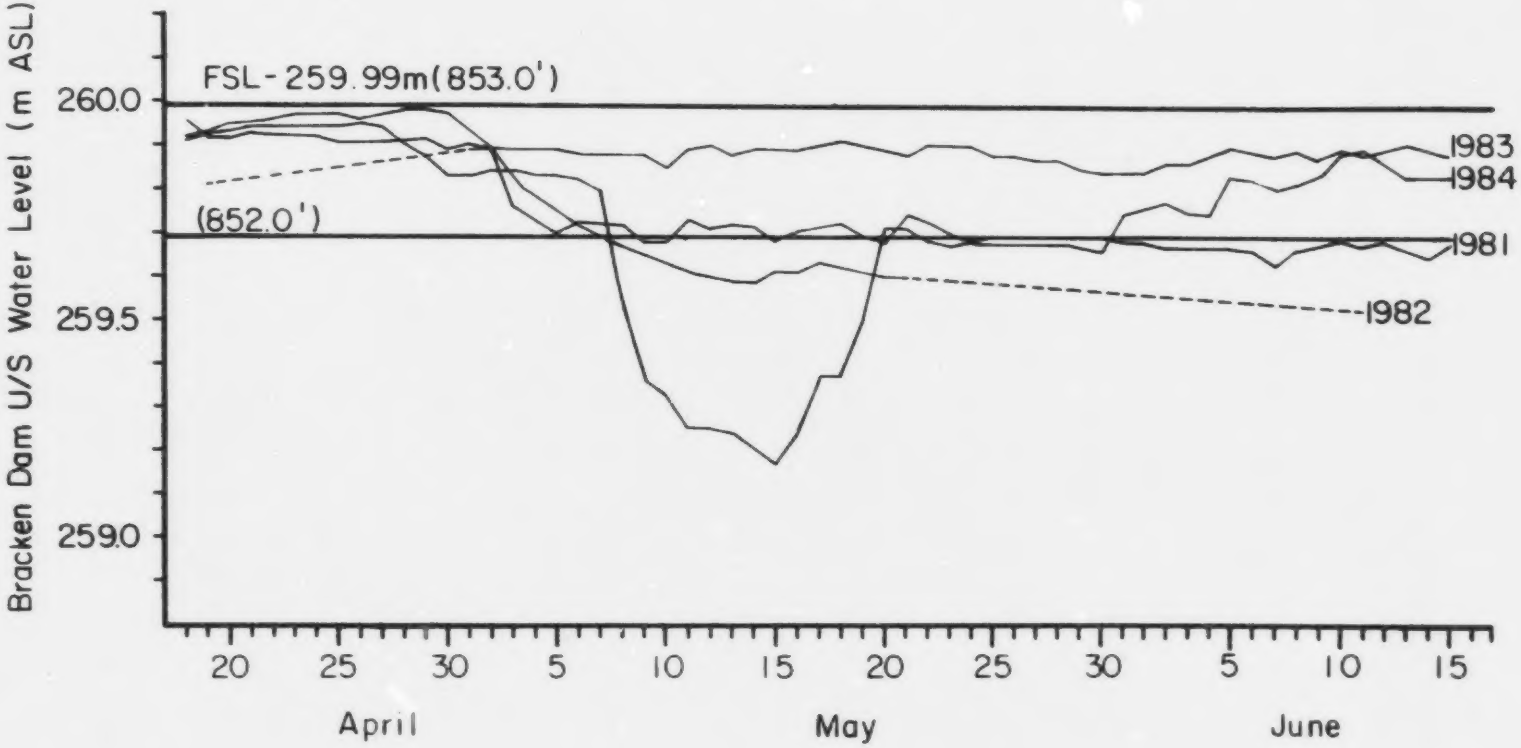

Fig. 53. Spring water levels on Saskeram Lake during four years (1981 - 1984) as compared to the FSL and 1 foot below FSL.

Early spring declines in water levels experienced on Saskeram Lake in 1981 and 1982 had the potential of causing a reduction in pike spawning success. The effect of the 0.6 m drop in water levels in May, 1981 (Fig. 53) is not known since there was no fall monitoring of pike leaving the marshes in that year. It is suspected that the negative impact, if any, on pike reproduction was minimal. In 1981, spawning pike were admitted into the Saskeram Marshes in May and only a small number (33) was estimated to have entered the marshes (Leroux, 1982). The pike that did spawn, probably spawned around mid-May when water levels began rising. In 1982, water levels dropped slowly, but steadily, throughout the suspected spawning and incubation period for pike. A large number of pike spawners (>20,000) moved into the Saskeram Marshes in 1982, but relatively few progeny from the parental stock were observed leaving the marshes in the fall (Leroux, 1982). These observations suggest the declining water levels may have exerted some mortality on the cohort at an early stage. Further evidence of this mortality will be discussed later.

Food Resources - Forage Fish

As indicated in the Methods, only limited obervations on forage fishes were made in 1984. These observations consisted of Beamish trap sets, poison sets using rotenone and limited counts of forage fish caught in the downstream traps at Bracken Dam, as well as notes on small fish going over the dam. The detailed results are presented in Appendices XXVIII, XXIX and XXX. The two most prevalent forage species in the Saskeram Marshes were the five-spine stickleback and fathead minnow. Judging from the Beamish sets, which were perhaps the least selective in terms of species composition of the catches, and observations at Bracken Dam, the most common forage species in the Saskeram Marshes in 1984 was the five-spine stickleback. Although appreciable numbers of fathead minnows were noted leaving the marshes between July 1 and September 30, they were soon overshadowed by sticklebacks. The sticklebacks did not begin appearing in any numbers at Bracken Dam until November 1 when approximately 1000 individuals were noted in the downstream traps. By November 6, the numbers of stickleback noted at the dam swelled to overwhelming proportions. The numbers were so large that they plugged the screens on traps and on several occasions caused the screen in the fish ladder to burst. Dense swarms of sticklebacks were observed above and below the dam. This massive exodus of sticklebacks was in contrast to 1983, when smaller numbers of sticklebacks were observed leaving the Saskeram Marshes.

The frequent observation of spottail shiners in the Saskeram Marshes in 1984 was at variance to observations in 1983. In 1983, no spottail shiners were encountered in catches at Bracken Dam. It is believed these fish were carried through the Saskeram Marshes by waters released from the Cumberland Marshes.

Young-of-the year pike were often caught in the marshes along with forage fishes. Young-of-the-year white suckers were infrequently encountered in the marshes. Other small fish such as the central mudminnow and the young-of-the-year walleye and juvenile carp, goldeye, and yellow perch which might serve as forage fish, were very rarely observed in the marshes. The principal forage fish for young and adult pike in the Saskeram Marshes would therefore be the five-spine stickleback, followed in order of importance by fathead minnow and probably young-of-the-year pike.

Summerkill Conditions

As previously noted (page 7), summerkills of young pike have been recorded in the Saskeram Marshes during the early 1960's. A summerkill event was also observed in the marsh during the first week of August in 1983. The summerkill was restricted to pike; no unusual mortality was observed in any other fish population. This event first became evident when several of the pike which had been tagged and released at Pyott's Crossing two days earlier were found floating dead on the surface in the same area (Table 30). The heaviest mortality of tagged pike coincided with the mortality observed in untagged young-of-the-year pike. Most of the pike (88%) tagged on August 3 were found dead one or two days later. A total of 1332 dead young-of-the-year pike were picked out of the lower Birch River from August 4 to 6 (Table 30).

The mortality of young pike was further evident from catches made in live capture gear. The majority of young-of-the-year pike caught in a Beamish net set at the outlet of Saskeram Lake died overnight during the August 4 to 6 period (Table 31). Prior to August 4 and after August 6, most of the pike remained alive in the Beamish net. Although dead pike were caught in the spillway trap at Bracken Dam, during the August 1 - 8 period (Table 31), these mortalities did not appear related to summerkill conditions. As will be shown later, summerkill conditions did not appear critical at Bracken Dam.

The mortality of pike which occurred during the August 1 - 8 period was related to high water temperatures and low dissolved oxygen levels. Surface water temperatures, as measured at Bracken Dam, rose

Table 30. Observations on a combined summerkill and tagging mortality of pike in the Pyott's Crossing area compared to a summerkill mortality of young-of-the-year pike in the lower Birch River during the period August 1 - 6, 1983.

Tagging Date	No. tagged	No. found dead *	No. of dead yoy pike +
August 1	18	2	-
2	19	4	2
3	26	23	3
4	16	9	468
5	-	-	376
6	1	1	488

* These pike were found floating dead on the surface 1 - 3 days following tagging.

+ These yoy pike were found in the lower Birch River the Saskeram Lake outlet and Bracken Dam.

Table 31. Live and dead captures of young-of-the-year pike in the spillway and Beamish traps during the period of observed summerkill conditions in the Saskeram Marshes.

	No. of YOY Pike			
	Spillway trap		Beamish trap	
Date	Alive	Dead	Alive	Dead
August 1	31			
2	3	30	22	
3		17	66	
4	25		127	190
5				77
6	10			66
7	38	22	79	12
8	6		14	2
Totals	113	69	308	347

* Beamish trap net was located in the Saskeram Lake outlet area.

sharply from 21^{o}C on July 31 to a peak of 26^{o}C on August 4 and 5 (Fig. 54). Dissolved oxygen levels in the lower Birch River at Pyott's Crossing which appeared to vary between 3 and 5.5 mg.l^{-1} during early and mid-July, but dropped to less than 1.5 mg.l^{-1} by late July and early August (Fig. 54). Details of dissolved oxygen testing results for the Saskeram Marshes from May through December in 1983 are presented in Appendix XXXI. According to Casselman (1978), these combined conditions (i.e. high temperature-low oxygen) were in the range that is lethal to pike (Fig. 55). Oxygen levels did not drop below 3 mg.l^{-1} at Bracken Dam and therefore were not critical to pike survival. These higher oxygen levels explain why there was no correlation between the mortalities of pike catches in the live traps (Table 31). The pike mortality noted in the spillway trap catches probably occurred from abrasions suffered as a result of water turbulence in the trap.

A summerkill was anticipated, but did not materialize in the Saskeram Marshes in 1984. This seems rather unusual since comparisons of weekly mean water temperatures at Bracken Dam indicate no major differences between summer temperature regimes in 1983 and 1984 (Fig. 56). In fact, average weekly temperatures during the hottest period (late July - early August) were higher in 1984 than in 1983. Comparison of daily surface water temperatures during July and August in 1983 and 1984 revealed a striking difference (Fig. 57). Although water temperatures approached 26^{o}C during the last week of July in 1984, they increased gradually. This contrasts to 1983, when temperatures rose sharply in August after declining two degrees at the end of July. Unfortunately, no measurements of dissolved oxygen were made during the high temperature period in 1984. Oxygen samples were taken only on July

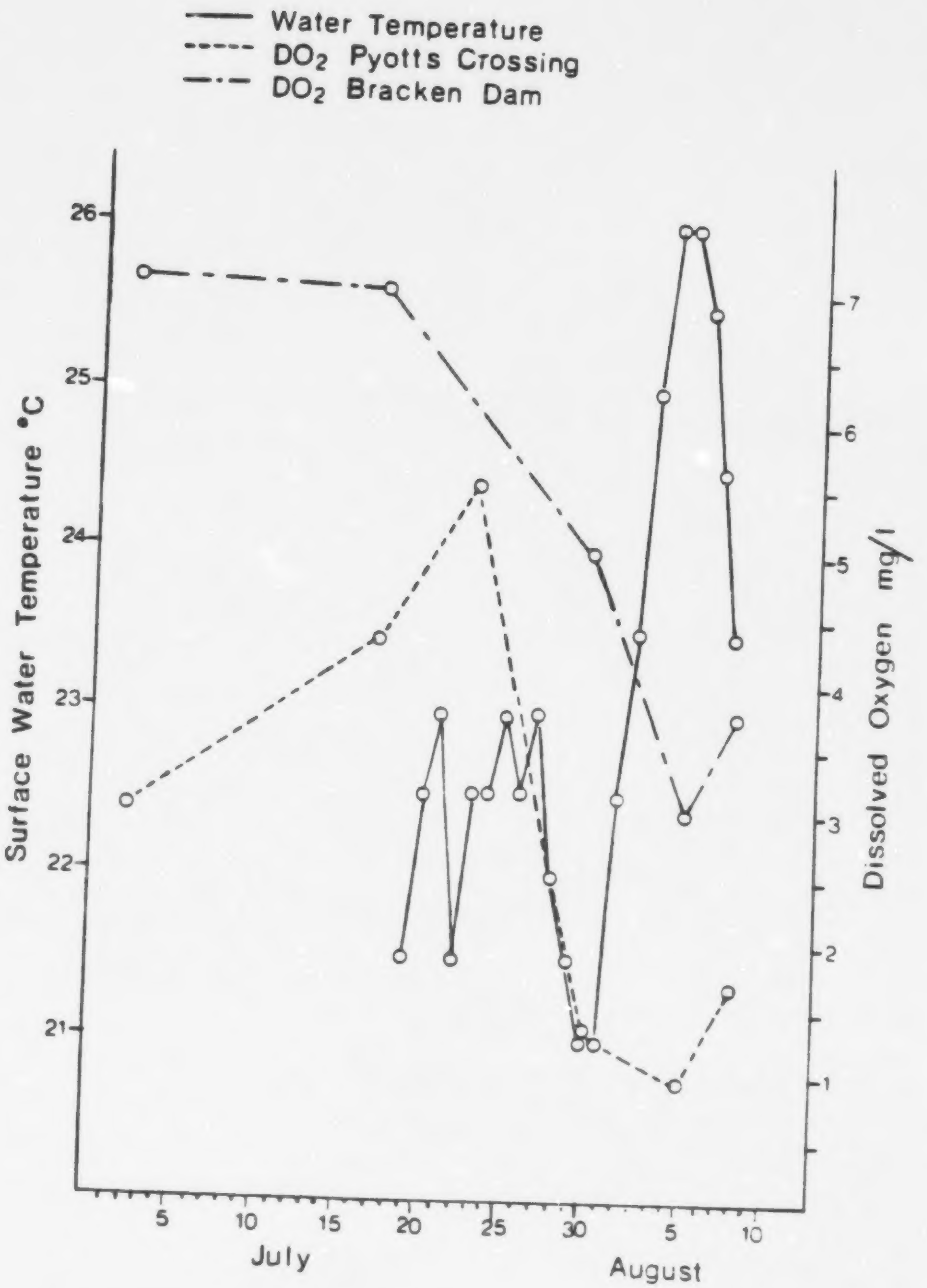

Fig. 54. Water temperatures and dissolved oxygen levels in the lower Birch River during the period of an observed summerkill of northern pike in 1983. Dissolved oxygen levels at Bracken Dam and surface water temperatures were recorded on the upstream side of Bracken Dam.

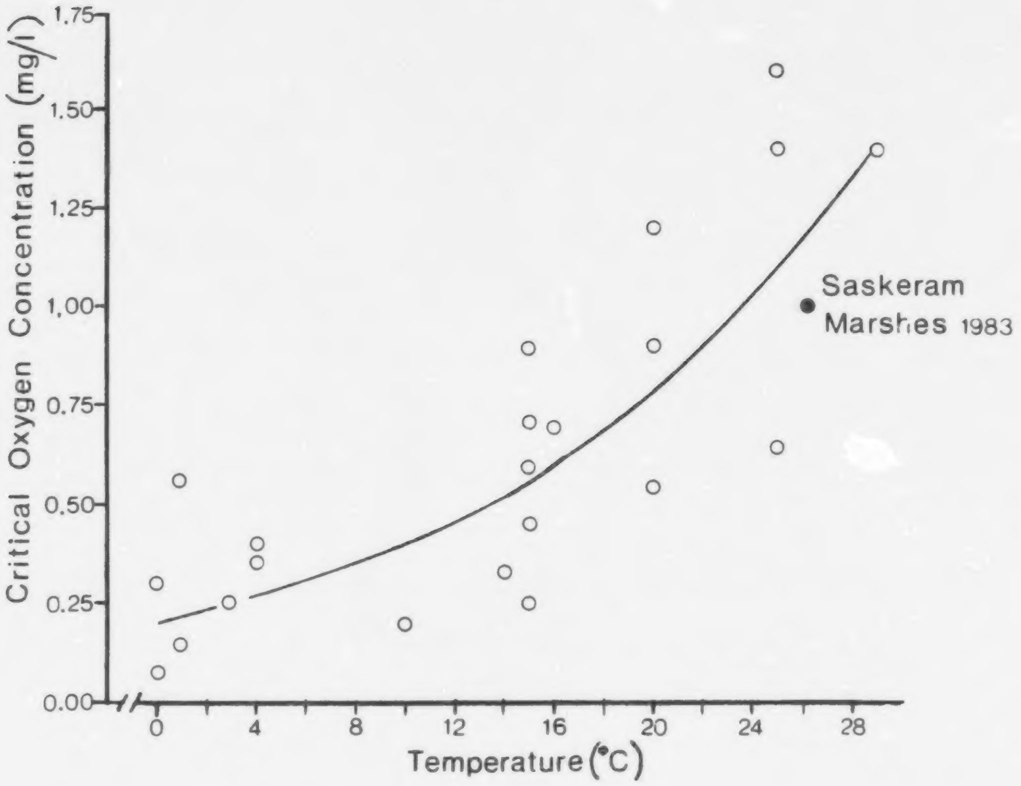

Fig. 55. Relationship between lower incipient lethal oxygen concentration for pike and temperature (from Casselman 1978). The solid dot shows the approximate lower oxygen level and water temperature in the Saskeram Marshes at the time of the 1983 summerkill of pike.

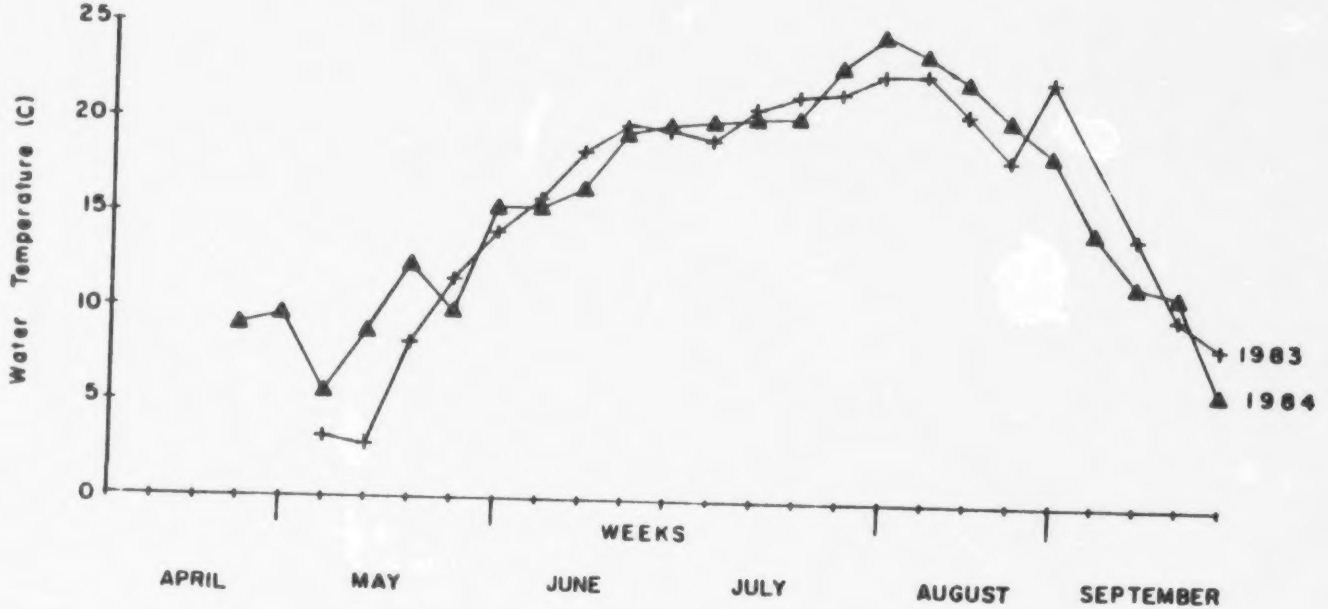

Fig. 56. Mean weekly water temperatures in the lower Birch River in 1983 and 1984. Temperatures were recorded by a thermograph set on the upstream side of Bracken Dam.

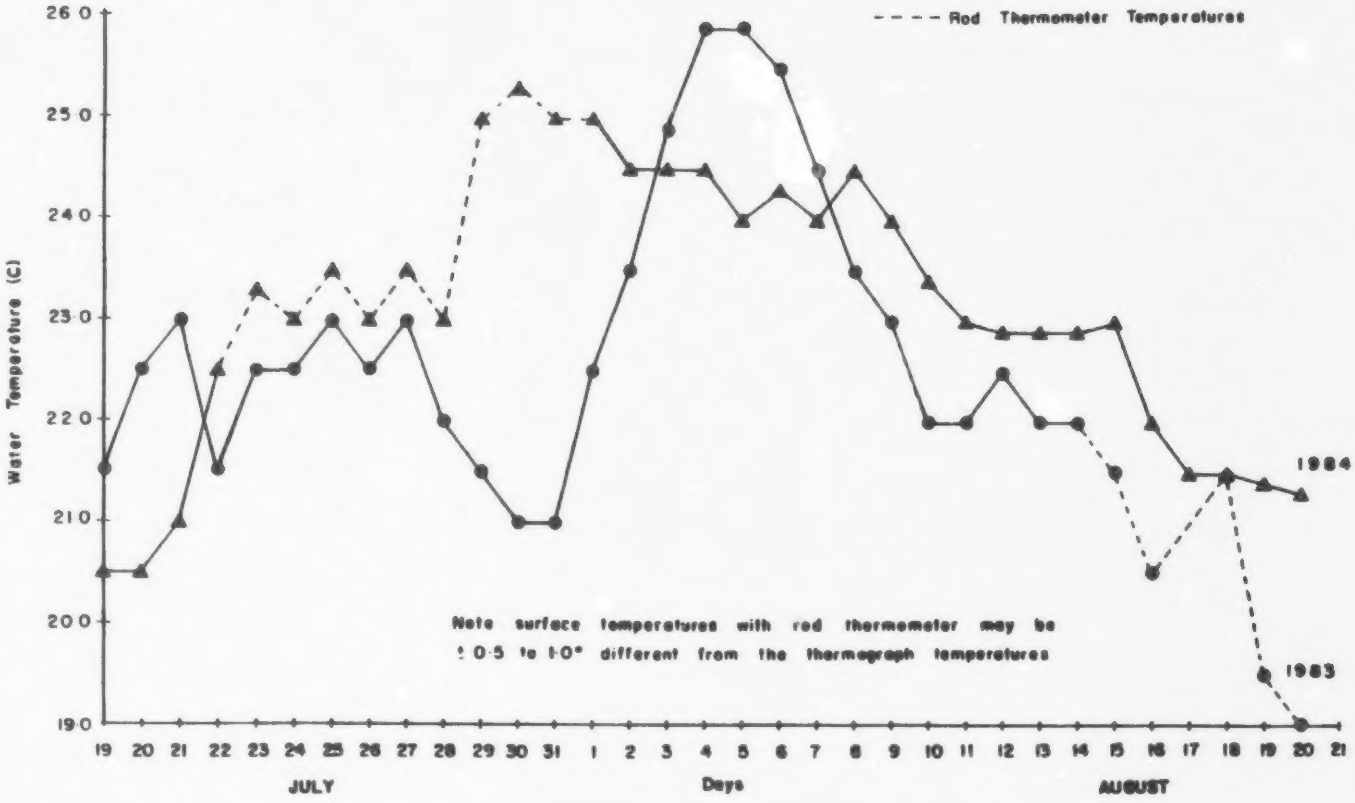

Fig. 57. Comparison of daily surface water temperatures in the lower Birch River during July and August, 1983 and 1984. Water temperatures were recorded on the upstream side of Bracken Dam.

3 and after August 10 in 1984 (Fig. 58). Temperatures and oxygen conditions at these times were not critical to pike survival. It is interesting to note that dissolved oxygen concentrations in the marsh were lower than those recorded at Pyott's Crossing or Bracken Dam in 1984 (Fig. 58). In 1983, oxygen levels in the Saskeram Lake area were intermediate to those observed at Pyott's Crossing and Bracken Dam.

Winterkill Conditions

Winterkills of fish in the Saskeram Marshes have been documented since the 1980/81 winter season. A summary of the observations made on these winterkills are presented in Appendices XXXII. The locale in which observations were consistently made each winter was the Cumberland Dam area. Checks were also made around the controls at Birch Lake and Lake Six in most years. Except for observations made at the Birch Lake control in December of 1981 and 1982, no efforts were made to quantify the extent or severity of winterkills. Attempts to capture fish by gillnetting to determine if they were still surviving were made on only two occasions. The first time was in December, 1982, when four pike were caught immediately below Cumberland Dam. In January 1984, a gillnet was set for 24 h downstream of Cumberland Dam. This netting produced 285 juvenile pike, 7 adult pike and 1 white sucker. Observations on catches by salvage fishermen in 1981/82 and 1984/85 did not provide any assessment of winterkills since the catches were generally made before oxygen depletion became serious.

Winterkills of fish, which might be considered as severe, were noted in three winters; 1980/81, 1981/82 and 1982/83. Although dead fish were encountered in 1983/84, they were mostly adult pike. Adult pike are much less common in the marshes than juvenile pike. Therefore, it is

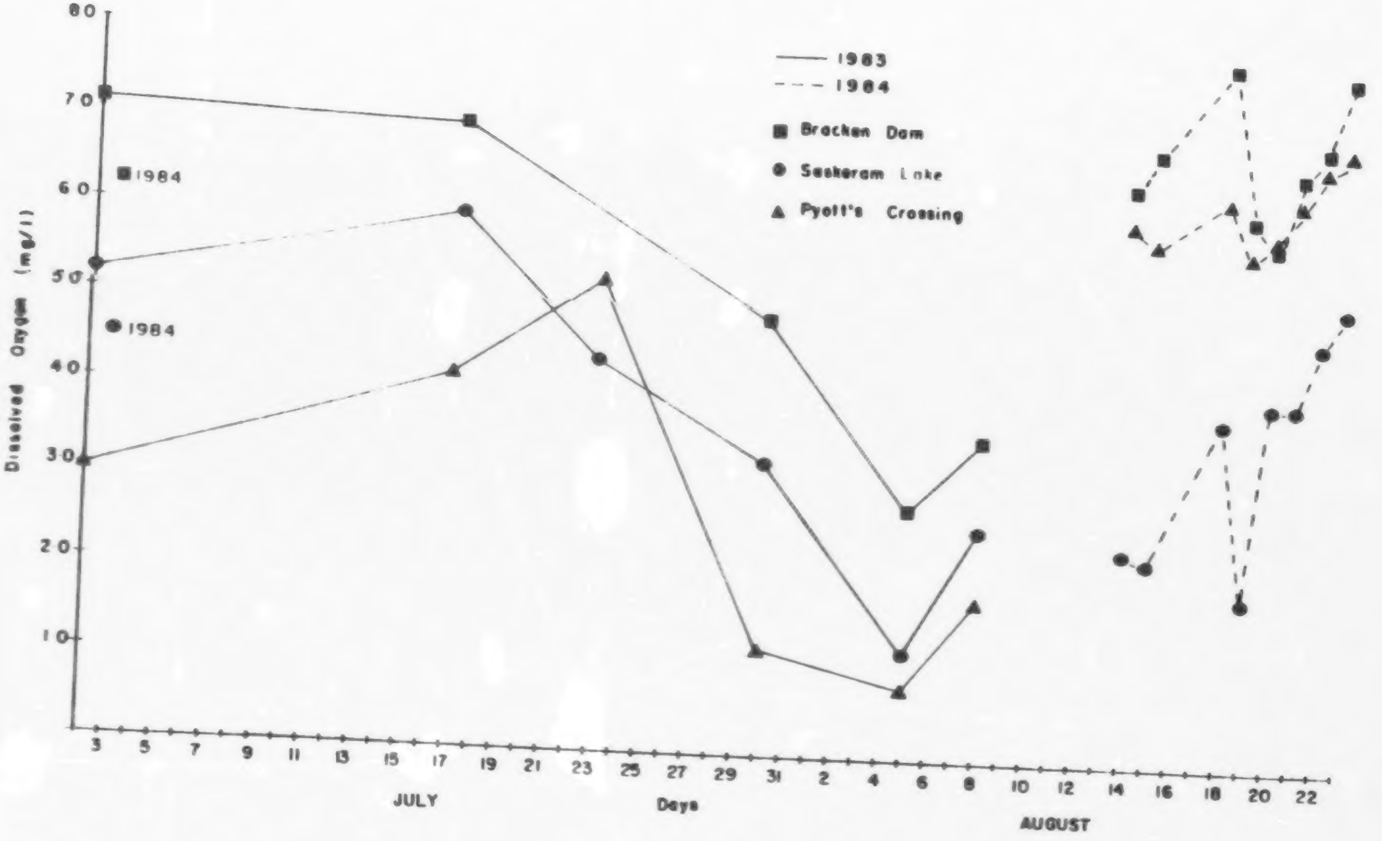

Fig. 58. Dissolved oxygen levels in the lower Birch River and the Saskeram Lake area over the period July 3 - August 22, 1983 and 1984.

conjectured that the winterkill was not a major one. Only a few thousand pike were noted in the 1984/85 winterkill.

The years of significant winterkills seemed to have some correlation with observations of winter oxygen levels. Oxygen testing at several locations in the Saskeram Marshes on February 28, 1981, indicated anoxic conditions throughout the area (Appendices XXXIIIa). A strong odour of hydrogen sulphide, indicating anaerobia, was also evident at sample locations at this time. In the following February, low oxygen levels (<1.0 mg.l^{-1}) were found below Cumberland Dam, around Birch Lake and in the area of the Lake Six control and a total winterkill seemed apparent (Appendix XXXIIIb). Before this, on December 14, 1981, the investigator reported many stressed juvenile pike below the Birch Lake control where the oxygen level at the time was 1.0 mg.l^{-1}. The limited oxygen testing conducted in 1982/83 indicated good oxygen levels below Cumberland Dam until January 12, 1983 (Appendix XXXIIIc). Several days after that, the onset of a severe winterkill seemed to be developing. A more comprehensive sampling of winter oxygen levels in the Saskeram Marshes was made in January and February, 1984. High oxygen concentrations (3-7 mg.l^{-1}) were found in the Cumberland Dam area in mid-January and gillnetting produced a good catch of pike. At this time dead fish were observed in the Birch Lake, Lake Six and Elm Creek control areas where oxygen levels of 0 to 0.3 mg.l^{-1} were recorded (Appendix XXXIIId). In February 1984, a "large fish kill" was reported at Cumberland Dam even though oxygen concentrations of 5.2 and 0.8 mg.l^{-1} were noted downstream and upstream of the dam (Appendix XXXIIIe). Similarly, dead fish were again recorded below Cumberland Dam on February 20, 1985, even though a large reservoir of well oxygenated water (1.8 to 4.0 mg.l^{-1}) existed as far as 1.0 km below the dam (Appendix XXXIIIf).

Observations on winter oxygen levels and fish kills in the Saskeram Marshes, apart from those given in Appendix XXXIII, were also made by other investigators. Dunn (1982) reported an oxygen concentration of 4.6 mg.l^{-1} on February 15, 1982, immediately below Cumberland Dam. A concentration of 0.4 mg.l^{-1} was also found at the west end of Birch Lake and in the Birch River immediately below the Birch Lake control. Concentrations of 0.1 to 0.9 mg.l^{-1} were found in the lower Birch River between Saskeram Lake and Bracken Dam. During the following winter season (1982/83), the following dates and dissolved oxygen levels were recorded by Crosley (1985) immediately downstream of Cumberland Dam; January 10, 1983 - 4.5 mg.l^{-1}, March 7, 1983 - 8.3 mg.l^{-1}. Resource officers from the Saskatchewan Department of Parks and Renewable Resources visited the Cumberland Dam area before and after the high oxygen concentrations were recorded on February 12, 1982 and January 10, 1983 (D. Walton, personal communication). On January 19, 1982, the resource officer visiting the area reported seeing thousands of dead sticklebacks and about 300 to 400 small dead pike in openwater below the dam. Many live sticklebacks were also seen at the same time. The water was reported to have "a rusty colour and a very stagnant odour". A month later (February 19), "a few dead pike . . . and thousands of sticklebacks" were observed. Some live sticklebacks were still present and the water still possessed a very stagnant odour and had a frothy surface. Live sticklebacks were observed below the Cumberland Dam until the end of March and were noted to be very abundant by early May. By May

3, spring breakup had commenced and the water quality was beginning two improve. The stagnant odour was no longer as strong.

More detailed observations by resource officers were made at the Cumberland Dam in the following winter season (1982/83). Gillnets set 50 m downstream of the dam on October 25, 1982 produced four large (approximately 0.5 kg) pike. The dissolved oxygen concentration at this time was 9.7 $mg.l^{-1}$ and the area was swarming with sticklebacks. One month later (November), the oxygen level was still 9.4 $mg.l^{-1}$. No large fish were noted, but large numbers of sticklebacks were still present. By December 3, some mortality of sticklebacks was becoming evident. On December 13, test netting produced four large pike. The following day some 300 to 400 dead yellow perch fingerlings and a few dead white sucker fingerlings were noted. At this time, the water was beginning to smell and a froth was forming on the surface. By January 19, 1983, a small number of dead pike (15-30 cm) and about 1000 dead yellow perch fingerlings were observed. Many dead sticklebacks were also noted. Two weeks later, on February 2, more dead than live sticklebacks were observed but some evidence was given that the river below the dam was opening up. By February 14, many live sticklebacks were observed. On March 30, no live fish could be seen, but a sizeable stretch (approximately 50 m) of water had opened up. The observer was uncertain whether the fish had moved to deeper water.

The foregoing observation of fishkills in the presence of what appear, in many cases, to be adequate dissolved oxygen levels are difficult to explain or reconcile. This difficulty arises, in part, from the fact that the field observations gathered in this study are limited in their value or usefulness for assessing what constitutes winterkill conditions in the Saskeram Marshes. Reliance has been largely placed on visual counts of dead (or live) fish. These observations do not consider what lies below the water surface or under the ice. Even winter gillnetting is restricted in what information it can provide. During low oxygen and low temperaturature conditions, fish may still be alive, but they may reduce their level of activity to such a low state that they become much less vulnerable to stationary catching gear.

Two factors which are known to create or enhance winterkill conditions are temperature and snow cover (Johnson and Moyle 1969). Increased ice thickness due to low temperature and heavy snow cover diminish the penetration of light and reduces photosynthetic activity and oxygen generation under the ice. In the three winter seasons in which the greatest fishkills appeared (1980/81 to 1982/83), below normal temperatures for a prolonged period were evident only one winter, 1981/82 (Fig. 59). Snowfalls generally appeared to be lower in those years in which large winterkills were observed (Fig. 60).

FISH PRODUCTIVITY OF THE SASKERAM MARSHES

The productivity of the Saskeram Marshes in terms of fish was determined primarily for northern pike. Pike are emphasized, since they were the most abundant of the large fish species which utilized the marsh. The productivity of the Saskeram Marshes in terms of pike was estimated for both 1983 and 1984. White sucker production from the Saskeram Marshes was only estimated for 1983.

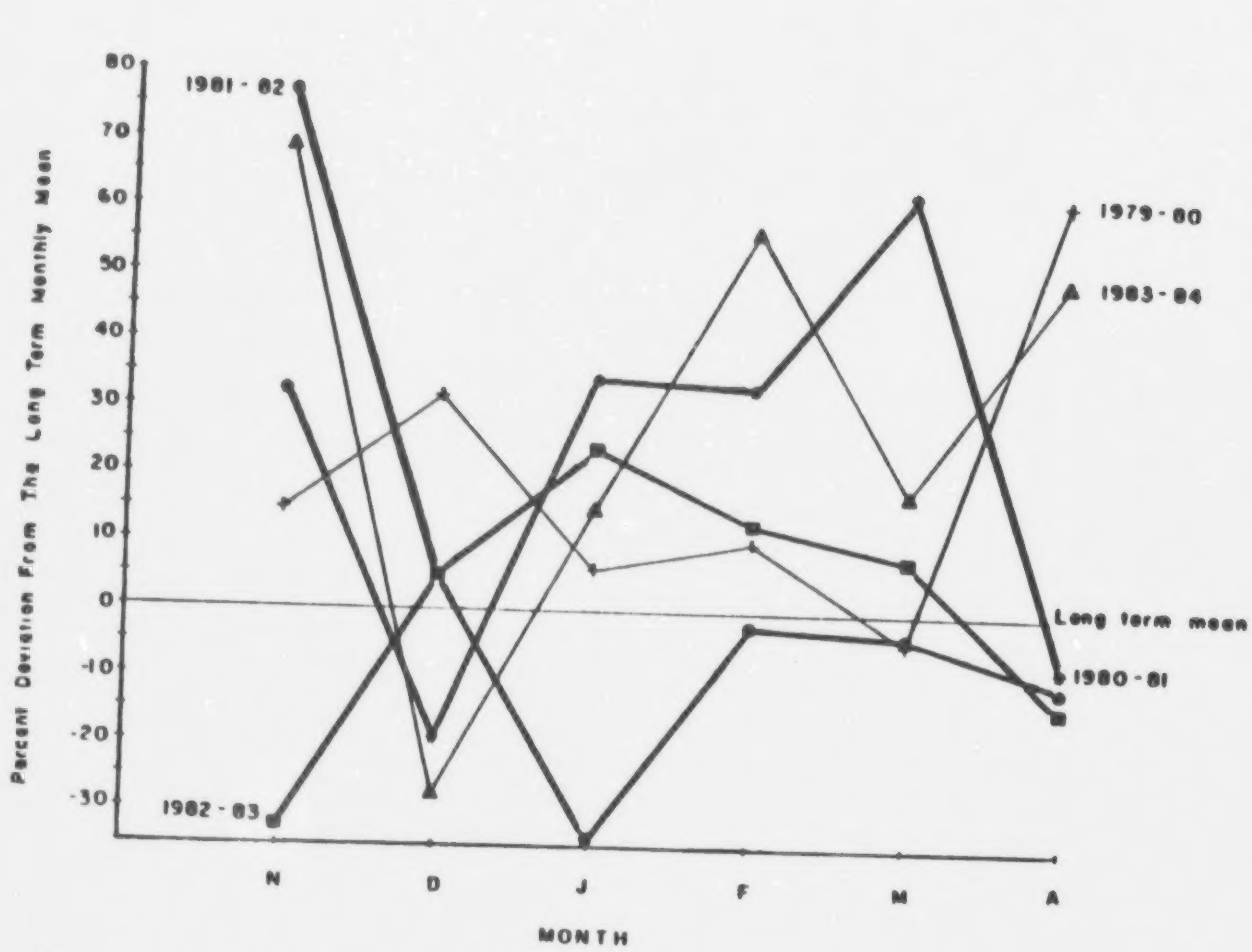

Fig. 59. Percentage deviation of mean monthly temperatures at The Pas for the winter seasons 1979/80 to 1983/84 from the long term (38 years) monthly mean. Heavy lines represent the years in which the winterkills were believed to be greatest.

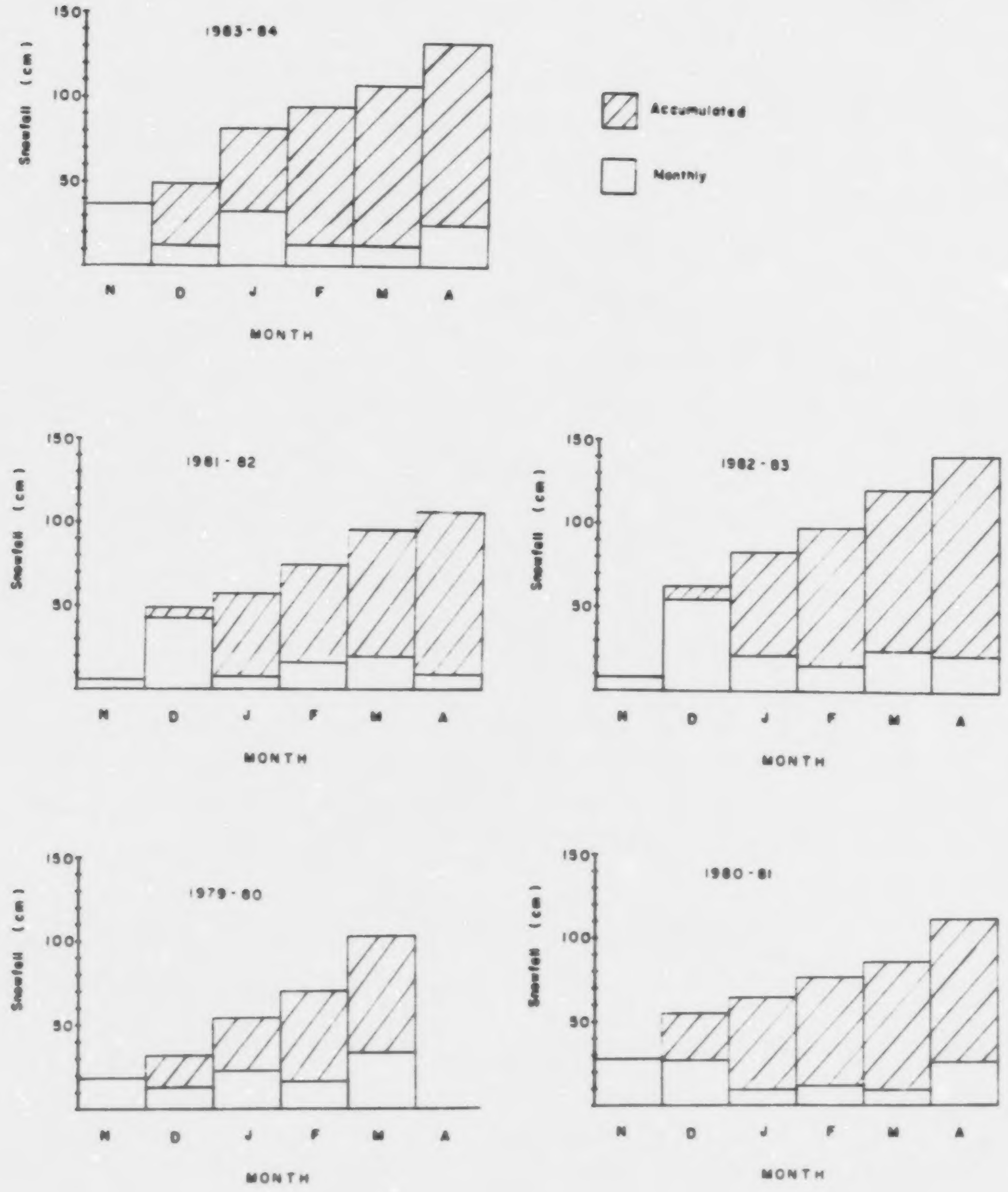

Fig. 60. Monthly snowfalls and accumulations at The Pas for the winter seasons 1979/80 to 1983/84.

Northern Pike -The productivity of the Saskeram Marshes was estimated from the numbers and average sizes of pike observed entering and leaving the marsh at Bracken Dam throughout both years. In the case of outward or downstream migrants, biomass or production was calculated for both adults and juveniles. A net production or production balance for the Saskeram Marshes was determined for each year by subtracting the weight of adult pike, which entered the marsh, from the combined estimated weight of the young-of-the-year and adult pike counted leaving the marshes. This was done under the assumption that many of the adult pike may be stranded in the marshes and therefore subjected to winterkill. This assumption is not necessarily valid, since many of the pike which were tagged on their ingress to the Saskeram Marshes were recaptured leaving the marshes later during the summer or autumn. Subtracting the biomass of upstream adults may be justified, however, since there are always some pike, both adults and juveniles, which remain within the marshes and are subject to winterkill conditions.

The estimated productions of pike from the Saskeram Marshes in 1983 and 1984 are shown in Table 32. In both years, there was a net contribution of adult pike to downstream areas; i.e. 119 kg in 1983 and 1477 kg in 1984. This net production of adult pike from the marshes may be due to three factors; a) to growth achieved while the fish are in the marshes, b) to the overwintering of some adults and young in parts of the marshes and c) to an influx of fish from the Cumberland Marshes. There is a possibility that overwintering of pike during the 1982/83 winter season accounted, to some extent, for the surplus in 1983. Much of the surplus observed in 1984 is believed to have come from discharges

Table 32. Estimated production of northern pike of all ages from the Saskeram Marshes in 1983 and 1984, expressed as the difference between the biomass of pike entering and leaving the marshes. The assumption is made that upstream migrants are lost due to winterkill.

	Upstream			Downstream			
Year/Age	n	Mean Wt. (kg)	Total Wt. (kg)	n	Mean Wt. (kg)	Total Wt. (kg)	Balance - kg (D/S - U/S)
1983							
Adults	318	1.11	353.0	536	0.88	471.7	118.7
Juveniles	-			34,753	0.13	4,517.9	4,517.9
All Ages	318	1.11	353.0	35,289		4,989.6	4,636.9
1984							
Adults	902	1.09	983.2	1,850	1.33	2,460.5	1,477.3
Juveniles				44,365	0.20	8,873.0	8,873.0
All ages	909	1.09	983.2	46,215		11,333.5	10,350.3

of water from the Saskatchewan River, via Cut Beaver Lake and the Cumberland Dam, through the Saskeram Marshes.

The biomass of young-of-the-year pike produced from the Saskeram Marshes in 1984 was almost two times that in 1983; 8873 kg vs 4518 kg (Table 32). These estimates are conservative, since in both years unknown quantities of fish escaped due to failures in the trapping devices. Also, a large number of young-of-the-year may have bypassed our trapping device in 1983, during periods of high discharges at Bracken Dam. Combining the young-of-the-year production with the biomass of adult fish, the Saskeram Marshes may contribute at least from 5,000 to 10,000 kg of pike each year to the Saskatchewan River.

The production of young-of-the-year pike from Saskeram Lake area was used to determine the productivity of the Saskeram Marshes for pike. Production values for both years were divided by the areas of Saskeram Lake at FSL (260 m ASL) and at elevations one and two feet below FSL (i.e. at 259.60 and 259.38 m ASL). Productivity values were calculated in terms of numbers and weight. Productivity in 1983 and 1984 varied from 4 to 11 fish per hectare and 0.5 to 2.3 $kg.ha^{-1}$, depending on the marsh area considered (Table 33).

Other species - Calculations of the production of adult and juvenile white suckers from the Saskeram Marshes indicated that a net loss occurred by allowing them into the area (Table 34). This loss seems, in part, to be due to a poor production of juvenile suckers from the marshes. One explanation for the low production of juvenile suckers may be that most of the young escape the marshes as drifting larvae. However, no larval suckers were observed in our drift net samples in

Table 33. Productivity of the Saskeram Lake area for young-of-the-year pike for 1983 and 1984 in terms of numbers and weight. Productivity is determined for several areas depending on the water elevation of Saskeram Lake.

Saskeram Lake Water Elevation (m - ASL)	Water Area (ha)	Productivity YOY Pike 1983 no./ha	1983 kg/ha	1984 no./ha	1984 kg/ha
259.99 (FSL)	8336	4.2	0.54	5.3	1.06
259.60 (852.0 ft)	6333	5.5	0.71	7.0	1.04
259.38 (851.0 ft)	3905	8.9	1.16	11.4	2.27

either year. It would appear that most of the white suckers hatched in the marshes remain and become trapped in the winter. The loss in adult sucker production from the Saskeram Marshes may also be lower than indicated in Table 34. As noted earlier (page 76), tagged adult white suckers left the marshes very soon after spawning. Since there was a large amount of spilling at Bracken Dam in 1983, many of the suckers admitted to the Saskeram Marshes may have escaped unnoticed.

Production calculations for walleyes and carp in 1983 also showed a net loss (Table 35). The reasons for these results, and particularly in the case of walleyes, may be similar to those mentioned for white sucker.

Table 34. Estimated production of adult and juvenile white suckers from the Saskeram Marshes in 1983, expressed as the difference between the biomass of white suckers entering and leaving the marshes. The assumption is made that all adults moving into the marsh are lost due to winterkill.

	Upstream			Downstream			
Age Class	n	Mean Wt. (kg)	Total Wt. (kg)	n	Mean Wt. (kg)	Total Wt. (kg)	Balance - kg (D/S - U/S)
Adults	388	1.46	566.5	217	1.46	316.8	-249.7
Juveniles	-	-	-	349	0.20	69.8	+ 69.8
All ages	388	1.46	566.5	566		386.6	-179.9

Table 35. Estimated production of adult walleyes and carp from the Saskeram Marshes in 1983, expressed as the difference between the biomass of fish entering and leaving the marshes. It is assumed adults entering the marshes are lost to winterkill.

	Upstream			Downstream			
Species	n	Mean Wt. (kg)	Total Wt. (kg)	n	Mean Wt. (kg)	Total Wt. (kg)	Balance - kg (D/S - U/S)
Walleye	108	0.95	102.6	11	0.95	10.5	- 92.1
Carp	69	7.58	523.0	26	7.58	197.1	-325.9

DISCUSSION

Freshwater wetlands or marshy areas have long been recognized as areas of generally high productivity and faunal diversity (Clark 1978, Good _et al_. 1978 and Ratti _et al_. 1982). Much of our understanding of the productivity of marshes relates to their use and control for the production of wildlife, especially waterfowl and muskrats (Weller 1978). In recent decades, attempts have been made through water management regimes to improve the productivity of marshes, especially those with expanses of open water. Drawdown and reflooding cycles have been imposed on marshes to enhance emergent macrophytic growth (Harris 1957 and Harris and Marshall 1963) and the abundance of invertebrates (Kadlec 1962, Voigts 1976, and Kaminski and Prince 1981) and subsequently wildlife production. In order to enhance emergent plant growth, the drawdown must occur during the summer so as to allow seeds to germinate. Overwinter drawdowns have been attempted (Beard 1973), but the purpose of this practice is to curtail submergent plant growth (e.g. _Myriophyllum_, _Nuphar_, etc.) and open up water for fishing. Summer drawdown operations have become an integral part of wildlife management on the Cumberland and Saskeram marshes (Mowbray and MacFarlane 1978, Phillips 1980 and Anonymous 1980).

Despite the wealth of information pertaining to wildlife productivity of marshes, relatively few investigations have been done on the fish production aspects of freshwater marshes. Where such information does exist, it generally deals with very small marshes under closely controlled conditions. For example, Fago (1977) reviews and reports on pike production from a number of managed marshes, most of which are less than 10 ha in size. Fisheries investigations of large marsh systems, such as found in the Saskatchewan River Delta, and at similar latitudes, are not common. The only previous major fisheries study in the Saskatchewan River Delta was that done by Royer (1966) on the Cumberland Marshes. The only study of fish productivity from a large marsh system in Manitoba is one by Janusz and O'Connor (1985). That study was conducted on the Netley- Libau Marsh, the last large marsh in Manitoba which has not been significantly impacted by water management. The present study on the Saskeram Marshes is unique in that it is the only investigation of fish productivity from a marsh system in which a portion has been subjected to drawdown and reflooding. Consideration is being given to the further management of other parts of the Saskeram Marshes, as well as other marshes within the Saskatchewan River Delta by drawdown. The findings and recommendations stemming from the present study therefore will be applicable to both the future regulation of the Saskeram Marshes, as well as other developments within the Delta.

Results from the present study and that of Leroux (1982) have confirmed that the Saskeram Marshes are important as a spawning area for several fish species. Those species which utilize the marshes for spawning are northern pike, white sucker, walleye and carp; of these, northern pike is the most abundant species produced by the marshes. Given the generally low flow conditions in recent years (Fig. 7), operation of the fish ladder in Bracken Dam is vital in maintaining fish access to the area. Opening of the fish ladder hinges on the timing of the spring migration of spawning fish. As indicated by June (1971), there can be considerable variation in the peak and duration of runs of spring spawning fishes such as pike. Although pike (Carbine 1942, Priegal and Krohn 1975), as well as walleyes (Eschmeyer 1950), and white suckers will begin moving upstream before the ice has disappeared from a lake or stream, this does not appear to happen in the Saskeram Marshes. The fetid outflow from the Saskeram Marshes, which continues until breakup is well developed and oxygen is recharged, prevents fish from moving upstream through Bracken Dam. Spawning movements of pike may begin when water temperatures reach 3°C (Clark 1950, Priegal and Krohn 1975). Pike were observed below Bracken Dam in May, 1983, when water temperatures were around 3°C. However, they did not move into the Saskeram Marshes apparently because of the poor quality of the water leaving the marshes at that time. Heavy movements of pike and white suckers appeared to begin once water temperatures reached 5°C. This is consistent with Koshinsky (1979), who found that the onset of spawning movements by both pike and white suckers in the Lac La Ronge area was more closely tied to a water temperature of 5°C than to stream discharge. Our results were different from those of Koshinsky (1979) who noted that the pike spawning run peaked just while the run of white suckers was starting. The spawning runs of pike and white sucker through Bracken Dam in 1983 and 1984 occurred at much the same time. Leroux's (1982) results suggested that the spring run of white suckers preceded pike at Bracken Dam. The onset of spawning movements of white suckers in the present study also differed somewhat from that found by Geen _et al_. (1966) and Walton (1980). They observed that the critical temperature initiating white sucker spawning migration was 10°C. The spawning run of walleyes, particularly in 1983, was coincident with the movements of pike and white suckers. Spawning temperatures for walleyes are consistent with those reported for northern pike (Scott and Crossman 1973). Movements of carp into the Saskeram Marshes began when water temperatures reached and remained above 14°C (Fig. 18). This agrees closely with McCrimmon (1968) who reported that carp moved inshore when water temperatures reached 15°C and began spawning at 17°C.

The spawning migration of fish through the Bracken Dam fishway appeared to occur during daylight hours (from 9 AM to 5 PM), although this tendency was not strong (Table 3). These results tend to agree with those of Koshinsky (1979) who found no consistent diel behaviour in pike during their spawning migration. Priegal and Krohn (1975) recorded similar results; pike were as active in the afternoon - early evening period as they were in the evening - early morning period. Conversely, Carbine (1942) and Franklin and Smith (1963) observed spawning-run pike to be most active during the hours of darkness; i.e. between 9 PM and 6 AM. Lawler (1969) similarly reported, based on changes in gillnet catches in Heming Lake, that pike, as well as walleyes, were most active during darkness, particularly between 11 PM and 6 AM. White suckers, on the other hand, were caught mostly between sunrise and sunset; i.e. between 5 AM and 9 PM. Geen _et_ _al_. (1966) observed that spawning white suckers moved upstream from noon onward, with a peak in movements just before midnight. Walton (1980) found that spawning suckers moved upstream during the night. Campbell (1971) also found that white suckers were most active during hours of darkness.

The spawning migrations of fish into the Saskeram Marshes did not last much longer than approximately 2 weeks (Fig. 17). About 70 per cent of the pike and 90 per cent of the white suckers moved into the Saskeram Marshes during the first 2 weeks of the 1983 and 1984 spawning period. Although movements of pike and white suckers into the marshes continued beyond the spawning run period, the numbers of these upstream migrants were much reduced (Table 2). The results agree with the findings of Koshinsky (1979) and Geen et al. (1966). Based on results presented by Koshinsky (1979) for several Lac La Ronge tributaries over 4 years, the average duration of pike spawning runs was 16 days. The spawning run duration in this instance is defined as the time between the first appearance of pike in the tributary and the date when 95 per cent of the run had passed. Geen et al. (1966) observed in 2 years of study that the spawning run of white suckers did not last longer than 10 to 15 days. Peak spawning movements of carp into the Saskeram Marshes did not last longer than 8 to 10 days (Fig. 18), and occurred well after the peak migration of pike and suckers.

Although the methods used to intercept fish on their movements from Bracken Dam into the Saskeram Marshes were found wanting, the data did suggest a strong tendency for the fish to quickly move upstream (Figs. 19, 20 & 22). The movement of fish throughout the marshes also could not be documented because travel by outboard motorboat in most of the area was impossible. However, available information such as recapture of several tagged pike at the Lake Six and Elm Creek controls and below Cumberland Dam indicated a rapid and wide dispersion, at least of pike, in the marshes.

The characteristics of fish spawning populations utilizing the Saskeram Marshes were not unusual. In other studies (e.g. June 1971 and Priegal and Krohn 1975), male pike may outnumber the females on the spawning grounds by as much as 8 to 1, but normally the sex ratio is about 2 to 1. The ratio in pike spawning runs intercepted at Bracken Dam varied from 2.4 to 2.9 males per female. The size distributions of pike in the spawning run into the Saskeram Marshes differed slightly annually, but fork length typically varied between 30 and 80 cm with modes around 50 cm (Fig. 32). This agrees with results noted for spawning pike by Priegal and Krohn (1975). They reported that average total lengths ranged from approximately 50 - 60 cm for males and 60 - 80 cm for females. Similar observations were made by June (1971). The average sizes for male and female white suckers in the 1984 spawning run (Fig. 40) were about 10 and 15 cm, respectively, greater than those recorded by Geen _et_ _al_. (1966) for spawning-run white suckers in Frye Creek, British Columbia. The size of female walleyes which moved in the Saskeram Marshes in May, 1983 (Fig. 41) were about 10 cm smaller than females which spawned in the marshes around Lake Winnebago, Wisconsin (Priegal 1970). Carp caught at Bracken Dam (Fig. 42) tended to be larger than the total lengths reported by Swee and McCrimmon (1966) for mature female carp in eastern Ontario.

The age compositions (Figs. 33 & 34) and mean ages at sexual maturity (Appendix XXVI) of the Saskeram Marshes pike are similar to the findings of other authors in that they reflect the early maturation of the species. Frost and Kipling (1967) reviewed a number of studies from a wide range of areas and listed the ages at which pike were found to spawn for the first time. These ages ranged from 1 to 6; age 2 was the most common age for males and age 3 for females. Our results most closely resemble those of June (1971) who observed that all male pike in Lake Oahe matured after age 1 and that females, although some may be mature at age 1, do not begin maturing in large numbers until age 2. Frost and Kipling (1967) note that it is growth rate or sizes and not age, which determines when pike will first spawn. This would perhaps account for the numbers of age 1 female pike observed in the 1984 spawning run. The two most prevalent ages of spawning-run walleyes at Bracken Dam (ages 6 & 7)were the same as those determined by Priegal (1970) for walleyes in the Lake Winnebago region. White suckers spawning in the Saskeram Marshes ranged in age from 2 to 12 years, with most being between 6 and 10. Geen et al. (1966) found that white sucker spawners were 6 - 10 years old, but suggested those ages were too low because scales did not provide a reliable measure of adult ages. Walton (1980), who used pectoral fins as we did, found that the most common ages of spawning white suckers were 5 to 7. Priegal (1976) examined the age distribution of a fall selection of white suckers and found most individuals (70.5%) in the sample to be ages 4 and 5. Scales were used to age the fish in Priegal's study. Carp ages in the present study, as determined from pectoral spines, ranged from 9 to 20 years with most distributed between 10 and 15 (Fig. 42). This is in contrast to Swee and McCrimmon (1966) who reported that the ages for carp on their spawning grounds varied mostly between 4 and 10 years. This discrepancy may have resulted from ageing techniques; scales were used in the latter case.

According to Fabricius (1950) and Fabricius and Gustafson (1958), major external stimuli which evoke spawning activity in northern pike are rising water temperatures, rising water levels and the presence of flooded vegetation, in particular in a dense mat of short vegetation. These stimuli perforce direct pike into shallow water, often no deeper than 18 cm (Scott and Crossman 1973) and usually less than 0.5 m deep, to spawn. Pike may spawn over a wide variety of vegetation (McCarraher and Thomas 1972). They have been reported to spawn on flooded winter wheat (Forney 1968) and mowed hay, broken hay bales or native prairie grasses (McCarraher and Thomas 1972). Most frequently pike have been observed spawning among various types of aquatic plants. Some examples are marsh grass - *Calamagrostis canadensis* (Carbine 1942), cord grass - *Spartina* sp. (Forney 1968), sedges - *Carex* sp. (Rawson 1932 and Fabricius and Gustafson 1958), reed grass - *Phragmites* sp., horsetails - *Equisetum* (Koshinsky 1979), water plantain - *Alisma* (Forney 1968), plantain - *Littorella* (Frost and Kipling 1967), wild celery - *Vallisneria* (Priegal and Krohn 1975), etc. . Franklin and Smith (1963) did not find pike spawning among stands of cattails (*Typha* sp.), although this was reported by Fago (1977) for pike released into a managed spawning - rearing marsh. In most cases, it would appear that pike spawning occurs among emergent aquatic macrophytes. Contrary to this, Frost and Kipling (1967) reported that pike in Lake Windermere spawn among submerged aquatic plants such as *Elodea*, *Myriophyllum* and *Nitella*.

Based on the above review, we feel more confident in suggesting that an important pike spawning area existed in the sedges and grassy areas found along the south and east fringes of Saskeram Lake. These areas were found between the 260 m contour and Saskeram Lake (Cross 1982), with generally shallow water depths. The sedges and marsh grasses found in these areas are adapted to a water depth of less than 25 cm. Certainly no evidence was found to indicate that pike spawned in the lower Birch River or deeper parts of the Saskeram Lake. Our attempts to capture pike eggs or larvae by pulling a fine mesh net through the vegetation (e.g. Phragmites and Typha) fringing the deep water channels in Saskeram Lake and the Equisetum stands along the edge of the lower Birch River were unsuccessful. Similarly, no drifting pike eggs or larvae were caught in the drift nets set above Bracken Dam, which would indicate that no spawning had occurred in the lower Birch River. The capture of adult pike at the Lake Six and Birch Lake controls also suggested the pike spawned in other areas than just Saskeram Lake.

The distribution of walleyes and white suckers, and consequently the location of their spawning areas in the Saskeram Marshes is unknown. When walleyes do spawn in marshes, they prefer areas with moving water over dense mats of vegetation (Priegal 1970). Walleyes might find these conditions below the water control structures for Birch Lake, Elm Creek or Lake Six. However, only one young-of-the-year walleye was observed in the lower Birch River at Pyott's Crossing to indicate that some spawning had occurred in the marshes. White suckers prefer moving water and rocky substrates (Scott and Crossman 1973). These areas do not occur in the Saskeram Marshes, but the presence of young-of-the-year white suckers in our samples attests to the occurrence of some reproduction. This reproduction does not appear to be too successful, however, considering the relatively large number of spawners entering the marsh and the small numbers of progeny leaving it.

Saskeram Marshes represent ideal spawning conditions for the carp. Since carp will spawn in water less than their own body depth, they would probably spawn in the same areas used by pike in Saskeram Lake. The fact that we observed only a few young-of-the-year carp in or leaving the marshes cannot be readily explained. Two possible reasons for this may be that the spawning population is too small or that the young-of-the-year carp remain in the area and succumb to winterkill. Another possibility is the predation of pike on the young carp. Mauck and Cable (1971) found that small carp (<110 mm) were highly vulnerable to pike predation. Janusz and O'Connor (1985) observed that carp, presumably young-of-the-year, were the most common prey fish taken by adult pike in the Netley-Libau Marsh. Predation of the young carp by pike, however, does not seem to be a feasible explanation in this case since no carp were observed in pike stomachs.

The pattern of emigration of adult pike, walleyes and white suckers coincided with the patterns described for these species by other investigators. Results from tag returns in the present study indicated that a high percentage of adult pike leave the Saskeram Marshes within several weeks of spawning, while a smaller proportion emigrate about 3 months later (Fig. 25). Franklin and Smith (1963) noted that around 60 per cent of adults left their spawning slough or marsh within 40 days after spawning, while some fish remained up to 107 days. The factors or mechanism responsible for the early exodus of adult pike are not known. These outward movements, however, may have been the result of the relationship between swimming activity in pike and water temperatures. Casselman (1978) found that the maximum swimming activity of pike occurred at temperatures between 19 and 20°C. In 1983 nd 1984, weekly average water temperatures of approximately 20°C were reached in the lower Birch River by the latter part of June (Fig. 56). Adult walleyes are not known to linger on their spawning grounds (Eschmeyer 1950). After the spawning period had passed, walleyes were no longer seen in the Saskeram Marshes. The data for white suckers are sketchy, but suggest that emigration occurs almost immediately after spawning (Fig. 27). This agrees with the finding of Geen et al. (1966), who observed that spent suckers began leaving the spawning streams within 10 days of the spawning run beginning. Walton (1980), who noted a similar phenomenon for suckers, also found a significant positive correlation between variations in stream discharge and numbers of fish moving downstream. Gaboury (1985) observed that the downstream movement of adult white suckers in the Valley River peaked approximately 3 weeks following the peak river discharge. The downstream recaptures of carp at Bracken Dam suggested they may leave the marshes soon after spawning. Otis and Weber (1982) concluded that adult carp scatter into the shallow areas during the summer months and seek out deeper water for the winter. Under these conditions it is expected that the adult carp would tend to remain in the Saskeram Marshes for the summer. However, this did not appear to be the case for carp which entered the Saskeram Marshes. No carp were recaptured leaving the marshes just prior to freeze-up. A few tagged carp were caught leaving the during midsummer; this suggested they left the marshes well before the onset of cold weather.

Movements of fishes upon leaving the Saskeram Marshes can only be discussed in the case of pike and walleyes. These were the only two species for which tag returns were sufficient to make some interpretation of their range in movements.

Approximately 2 per cent of the pike returns outside the Saskeram Marshes were more than 60 km away from Bracken Dam, and most were from downstream areas of the Saskatchewan River (Table 12). The most distant recovery was from the Saskatchewan River in the Cumberland House area[1], which is upstream of the release site. Moen and Henegar (1971) similarly noted that while most recaptures of tagged pike in Lake Oahe, a Missouri River mainstem reservoir, were downstream of the release site, the most distant recoveries were from upstream areas. Pike leaving the Saskeram Marshes, however, exhibited a strong proclivity to remain within 10 km of Bracken Dam (Table 12). Almost half the recaptures were only 1 km away from the release site. Similarly, Koshinsky (1979) reported that 59 per cent of tagged pike recoveries in Lac La Ronge were within 3 km of the release site. These results are not unlike those reported by Mann (1980) for pike in the River Frome, England. He found, using probit analysis, that there was both a static and mobile component of the pike population. In this instance, the static component also made up the greatest proportion of the population and was within 0.25 km of the release site. Mann (1980) further observed that the younger pike (ages 0 and 1) tended to be more widely dispersed, whereas the older pike remained near the release location. Although older pike may be more restricted in their movements, they do not, according to Diana _et_ _al_. (1977), establish well defined home ranges.

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[1] During the writing of this report, a tagged pike and white sucker were reported caught by a commercial fisherman in Cumberland Lake and two tagged pike were caught by anglers just below the Squaw Rapids Dam. Several tagged pike have also been recaptured in the Root-Reader system.

Post-spawning movements of walleyes determined in a number of studies have been reviewed by Priegal (1970). In most cases, females depart from the spawning areas first, with the males sometimes lingering for a short time. The walleyes may remain near their spawning areas for awhile after spawning. Rawson (1957) observed that in the post-spawning movements, walleyes moved back into Lac La Ronge, but remained inshore near the stream in which they had spawned. He reports they moved into deeper water in July, where they scattered and intermingled with walleyes from other spawning runs. The wide disperison and intermingling of post-spawning walleyes have also bee observed by other investigators (e.g. Stoudt and Eddy 1939, and Eschmeyer 1950). It seems that walleyes may also return to specific areas of home feeding ranges which they occupy during the summer - fall period. Forney (1963) examined the dispersion of three spawning runs in Oneida Lake, New York, and concluded that these spawning populations did not randomly mix during the late summer. Ferguson and Derksen (1971) also observed that post-spawning walleyes from the Thames River showed a strong tendency to move to the St. Clair River and southern Lake Huron where they remained throughout the fall and possibly for some time during the winter. This behavioural trait of walleyes to move to summer ranges is further reviewed by Olson _et al_. (1978). In the present study, the walleyes moved downstream as far as Cedar Lake, a distance of approximately 90 km (Table 13). Walleyes tagged and released in the area of Cedar Lake have also been recovered in the Saskatchewan River around The Pas. This wide ranging behaviour of walleyes is not unusual. Doan (1942), Wolfert (1963) and Ferguson and Derksen (1971) have reported walleyes, which were tagged in or around Lake Erie, being recaptured more than 300 km from their point of release.

Results from the present study suggested the possibility of some homing instinct in pike to return the Saskeram Marshes (Table 14, Fig. 30). Koshinsky (1979) concluded that pike in Lac La Ronge exhibited a strong tendency to home to specific spawning areas and that there was little straying between spawning areas. Similar observations were made by Carbine and Applegate (1946). They, along with Forney (1968), further concluded that pike will tend to return to their natal areas. Researchers in Europe have also found evidence of homing in northern pike (Machniak 1975). Franklin and Smith (1963) conversely reported no homing of pike to spawning grounds in their study of Lake George, Minnesota. However, it must be noted that the area of this lake is less than 300 ha and considerably smaller than the lakes studied by Carbine and Applegate (1946) or Koshinsky (1979).

The tendency for tagged walleyes to be recaptured near or at Bracken Dam one year after release and during the spawning season (Tables 13 and 14) suggests a homing instinct or behaviour. Homing or the consistent return of tagged walleyes to the same spawning area in ensuing years has been reported by various other investigators (e.g. Eschmeyer 1950, Smith _et al_. 1952, Rawson 1957, Crowe 1962, Olson and Scidmore 1962, Forney 1963, and Priegal 1968). In a more recent analysis of walleye movements, Olson _et al_. (1978) hypothesize that homing in this species is an adult learned behaviour and is not due to imprinting. They further speculate that extirpated spawning runs may be re-established by introducing adult spawning walleyes.

The recaptures during the 1984 spawning run of 53 white suckers which had been tagged and released at Bracken Dam in 1983 suggests this species also exhibits a homing tendency. Olson and Scidmore (1963) observed a strong affinity of white suckers in Many Point Lake, Minnesota, for a particular spawning site. Their observation that some individuals in the population had a stronger homing behaviour or that repeated returns to a spawning area reinforced the homing behaviour suggests that homing movements by white suckers, as by walleyes, is a learned behaviour.

Habitat conditions in the Saskeram Marshes during the openwater period did not, for the most part, appear to be limiting to most species utilizing the area. Conditions within the marshes appear consistent with spawning and nursery requirements for northern pike. Given water level conditions close to or at full pond elevation, sizeable areas around Saskeram Lake are available which have vegetation ideally suited for pike spawning. However, because of the shallowness of these areas, they are prone to extensive dewatering with only a minor drop in water level. It is speculated that steadily declining water levels in the Saskeram Lake area during the spawning-incubation period in 1982 was a factor in the apparent year class failure reported for pike in that year by Leroux (1982). The significance of water level to reproductive success in pike has been examined by other investigators. Johnson (1957) found some positive correlation (r=0.61) between the ranked year class strength of pike and water levels. He ascribed the lack of closer correlation to uncertainties in the data and to a possible depressing effect of a strong year class on subsequent cohorts. Koshinsky (1979), on the other hand, found no positive correlation between spring water levels and pike spawning success in spawning areas around Lac La Ronge. Similar results were reported by Hassler (1970) and Osborn et al. (1981) for pike in reservoir lakes. The latter authors, however, did report good pike reproduction associated with rising spring water levels. Sudden drops in water levels may also affect the ability of fish to spawn. June (1970) found that an increased incidence of atresia in female pike was associated with very rapid drops in water levels. Given these findings, it is evident that in order to provide for successful reproduction of northern pike in the Saskeram Marshes, an essential minimum requirement would be to ensure stable water levels throughout the spawning and incubation period. Optimum conditions for pike reproduction would be provided under gradually increasing water levels during the spring. Stable or rising water levels would also benefit most other fish species spawning in the marshes.

A variety of other abiotic factors, which are essentially uncontrollable, may effect the reproductive success of fish in the Saskeram Marshes. Some factors which have been examined by others, particularly with reference to pike, include water temperatures, iron, toxic gases and silt. Of these parameters, water temperature is perhaps the most significant. Hokanson et al. (1973) report that water temperatures near 12°C provide optimum conditions for pike embryonic development. Hassler (1970) noted that rapid temperature fluctuations may contribute to a year class failure in pike. Weather conditions experienced during the last year of the present study underline the sudden changes in temperatures which may occur in the Saskeram Marshes area. Heavy snowfalls during late April, 1984, resulted in a 10.5°C drop in water temperature at Bracken Dam over a 5-day period (Appendix Ib).

Air temperatures fell below freezing on April 28 and remained there for 5 days. Judging from the previous high water temperatures and sexual condition of the pike, spawning had already begun. It is not known, however, whether this sudden drop on water temperature resulted in any significant mortality of the spawned eggs. Hassler (1970) reported that a sudden drop in water temperature from 10.5 to 7.5°C, which persisted for some time, was associated with 75 per cent mortality in pike eggs during early development. He also found that when temperatures dropped to or remained near 5°C,egg mortality was essentially complete. He further observed that pike eggs which were spawned at higher, less variable temperatures later in the spawning season had a higher percentage hatch. In a more recent investigation, Hassler (1982) confirms his earlier observations; i.e. for normal hatching of pike eggs, incubation temperatures should be 6°C or more. Hassler (1982) found that pike embryos were most sensitive to temperature change within the first 5 h of development, the period when the initial cleavages of the egg occur. If pike spawning in the Saskeram Marshes peaked with water temperatures, then most of the eggs that had been deposited would have been well developed and less sensitive to any sudden temperature changes. Although there may have been some egg mortality, and most certainly a temporary curtailment of embryonic development, these effects do not appear to have been sufficient to decimate the 1984 year class of pike. The production of young-of-the- year pike from the Saskeram Marshes in 1984 was apparently better than in 1983 (Table 32). Water temperatures in the Saskeram Marshes in 1983 (Appendix Ia) rose gradually throughout the spawning incubation - hatching periods and were within the optimum hatching range (6 - 21°C) reported by Hassler (1982) for pike. Following the cold snap in 1984, water temperatures remained above 6°C, but fluctuated daily as much as 3°C. It is doubtful, however, that these temperature changes effected any mortality of pike eggs or larvae. Hassler (1982) found that pike embryos and yolk-sac larvae were very tolerant of temperature change within the optimum range of 6 - 21°C.

Under anaerobic conditions such as may exist in marshes, iron may reach concentrations which are toxic to fish and other aquatic organisms. Toxicity levels of iron to fish have been reported in the range of 1 - 2 $mg.l^{-1}$ (US Environmental Protection Agency 1976). A concentration of 0.3 $mg.l^{-1}$ iron has been established as a criterion for the protection of aquatic organisms in the Great Lakes (Great Lakes Water Quality Board 1976). Franklin and Smith (1963) reported iron concentrations in a pike spawning slough as high as 65.5 $mg.l^{-1}$. Most (80% or more) of this iron was in the insoluble form. They suggested that the high iron content, along with a rapid temperature change, may have been related to the low survival of a year class of pike. Concentrations of iron (extractable) in the Birch River have been reported as high as 6.9 $mg.l^{-1}$ during late winter, but drop appreciably after spring breakup (Crosley, 1985). The concentrations of iron in the backwater areas of the Saskeram Marshes immediately following breakup and its possible effects on the reproduction of pike or other fish species in the marsh are unknown. It is perhaps unimportant in most years, but may be significant during dry years when stagnant conditions following breakup might prolong the dissipation of the winter accumulation of iron.

Gases such as methane and hydrogen sulphide (H_2S) which are commonly generated in marshy conditions, may be toxic to fish eggs or larvae. Adelman and Smith (1970) demonstrated that very low concentrations of H_2S (< 1ppm) may be lethal to pike eggs and sac fry and in some instances cause malformations of sac fry. Royer (1971) attributed poor returns from pike fry plantings in rearing marshes in part to the possible lethal effects of H_2S gases. Royer observed that the planted pike fry were unable to attach to vegetation and settled to the bottom where the concentration of H_2S gases would be higher. In the Saskeram Marshes, H_2S gases probably did not cause a significant mortality of pike or walleye eggs, as both species prefer to spawn over dense vegetation mats. These would buffer them from the higher gas concentrations at the mud-water interface. The newly hatched pike larvae would be able to remain off the mud bottom because of their habit of attaching to the vegetation. Since newly hatched walleye larvae are incapable of attaching to vegetation or swimming, they may be prone to settling to the bottom and becoming exposed to lethal concentrations of marsh gases.

Siltation may be another major factor of mortality of fish eggs. Hassler (1970) noted that a siltation rate of 1.0 mm per day was associated with a near total mortality of pike eggs. Gaboury (1985) observed an inverse relationship between silt deposition and walleye egg survival. It is doubtful, however, that siltation is presently an important factor to egg survival in the Saskeram Marshes. Because the area is so heavily vegetated, the opportunity for the suspension and movement of silt by either water or wind activity is minimal.

Except for limitations imposed by fluctuating water levels, the Saskeram Marshes appear ideally suited in most respects, as a spawning area for pike. Approximately 90,000 young-of-the-year pike were produced from the marshes during 1983 and 1984 (Table 2). The information compiled in 1983 permits some estimate of spawning success or survival of eggs and young pike in the marshes. The 1984 data cannot be used since the number of young-of-the-year recruited from upstream areas with water releases at Cumberland Dam is unknown. The potential egg deposition in 1983 can be calculated from the estimated number of mature females and the average fecundity of similar sized pike, as determined from the literature. During the 1983 spawning season, the approximate number of mature pike estimated to be present in the marshes was 3000 (Table 15). Most of these fish had overwintered in the marshes; only 213 had entered the Saskeram Marshes during the spring spawning run. The sex ratio of pike intercepted at Bracken Dam varied between 2.5 and 3.0 males per female. Applying these ratios to the population estimate, some 1000 to 1200 females were in the marsh. The size and range of females in the 1983 spawning run was 34 - 55 cm (Fig. 22). The average fecundity for pike of this size range is approximately 30,000 eggs (Vessel and Eddy 1941, Johnson and Moyle 1969, Scott and Crossman 1973). Assuming all the female pike spawned in the Saskeram Marshes in 1983, the potential egg deposition is in the order of 30 to 35 million eggs. Approximately 35,000 young-of-the-year pike were enumerated leaving the Saskeram Marshe in 1983. (This number may have been actually 45,000 to 50,000, since an unknown quantity of pike escaped the marshes during breakdown of our trapping gear.) This represents a survival rate from egg deposition to the end of the first summer of about 0.1 per cent. This survival rate may have been higher, as the assumption that those pike which overwintered in the marshes may have also spawned there is not necessarily valid. Koshinsky (1979) and Diana and Mackay (1979) noted that gonad development in female pike occurs over the winter. Although both sexes grow over the winter (Diana 1983), food requirements are crucial to the female if ovarian development is to occur. Casselman and Harvey (1975) speculated that female pike are more susceptible to winterkill possibly because of their high oxygen demand during ovarian development. Given the possible limitations imposed on pike by low winter oxygen conditions in the Saskeram Marshes, it is questionable whether the overwintering adults were able to spawn. If they did not, egg deposition would be much lower and spawning survival estimates would have to be revised upwards. This estimated survival rate of pike spawn is discussed further on page 212.

In the present study, the feeding habits of young-of-the-year pike could not be documented until July in both years. It is known, however, that the young pike will begin active feeding 9-10 days after hatching when they are about 10 mm long (Toner and Lawler 1969). Initial food organisms of young pike are Entomostraca; i.e. all small freshwater crustaceans. According to Embody (1910), Hunt and Carbine (1951) and McCarraher (1957), the food items selected by young pike follows a predictable sequence as the pike increase in size. These dietary changes proceed from microcrustaceans to insects to other invertebrates. Hunt and Carbine (1951) ascribed the following size ranges of pike to the three dietary stages:

a) 11 - 25 mm mainly Entomostraca

b) 26 - 50 mm mainly immature aquatic insects

c) >50 mm mostly fish and invertebrates

These size-related feeding changes may, of course, not be typical of all populations. For example, Franklin and Smith (1963) reported that crustaceans such as copepods, cladocerans and amphipods (Entomostraca) were important in the diet of pike until lengths of 120 mm or more had been attained. Koshinsky (1979) found that Entomostraca were important in the diet of young Lac La Ronge pike up to 70 mm and that aquatic insects were consumed until the pike reached lengths of 100 mm. The size at which pike become piscivorous may also vary. Kipling (1983) reported young-of-the-year pike will begin eating fish at a length of 35 mm and will take individuals half their own length. Young pike may pass directly from a diet of microcrustaceans to fish (Frost 1954). It is recognized, however, that young pike in general are opportunistic feeders and that their diet may vary according to the habitat in which they are found (Holland and Huston 1984).

When samples of young-of-the-year pike were obtained from the Saskeram Marshes, individuals had already reached lengths in excess of 10 cm. At this stage in 1983, they were still foraging predominently on invertebrates (Table 27), most of which were entomostracans (i.e. amphipods and copepods). This heavy predation by the young pike upon amphipods does not appear unusual since these organisms were ubiquitous in the openwater areas throughout the marshes. One of the authors (D.G.G.) observed during mid-summer trips through the Saskeram Lake area that young-of-the-year pike were prevalent in the openwater patches. Holland and Huston (1984) similarly reported that by late summer, young-of-the-year pike were more common in the less vegetated areas of marshy backwaters along the Mississippi River. They attributed this movement into more openwater situations to declining oxygen tensions in the more heavily vegetated areas.

In contrast to the 1983 results, invertebrates were not as significant a food item for young Saskeram pike in 1984 (Table 28). In July and August, 1984, amphipods were ingested by young pike about half as frequently as in 1983. The reason for this difference is not known, but perhaps may be related to a change in the invertebrate community of the marshes. Ostracods were observed in great abundance in the Beamish traps in 1984, but not in 1983. Since no quantitative sampling of the seston was done, it can only be speculated whether or not amphipods were displaced by the ostracods. Nonetheless, ostracods were not found to constitute a significant dietary item. The observation of ostracods in the stomachs of young pike was generally associated with a heavy catch of ostracods in the trap net. This suggests the pike had consumed the ostracods only while in the net. Various authors (e.g. McCarraher 1957, Franklin and Smith 1963, Priegal and Krohn 1975 and Fago 1977) have found that ostracods are seldom eaten by pike.

Although fish were frequently observed in the diet of young pike from July through September in 1983, they did not surpass invertebrate food items until October (Table 27). This is in sharp contrast to the results obtained in 1984, where underyearling pike appeared to be feeding primarily on fish throughout the entire summer.

Overall, a slightly higher proportion (64%) of the young pike sampled in 1983 had fed on fish than had in 1984 (57%). However, this may have been due to bias introduced by the early winter (December - January) samples in 1983 in which the selected food items were almost exclusively fish. Brook (five-spine) sticklebacks were most frequently preyed upon by young pike in 1983. Although pike will avoid feeding on sticklebacks because of their spines, this avoidance may be diminished as pike grow to a size where the stickleback's spines are no longer a deterrent. Koshinsky (1979), for example, reported that as pike grew larger, ninespine stickleback became more acceptable as food. Fathead minnows appeared to be more prevalently used as a forage fish in 1984 (Table 28). Although fathead minnows were not more abundant than sticklebacks in the Saskeram Marshes in 1984, casual observations of small fishes in and leaving the marshes (Appendices XXVIII - XXX) suggest that the fathead minnows were actively leaving the area during the summer. This movement may have rendered them more vulnerable to predation of the young pike.

Only a few isolated instances of cannibalism were observed among the young-of-the-year pike. The absence of any marked degree of cannibalism in the Saskeram Marshes is probably related to good growth and the general uniformity in individual sizes within the cohort. Craig and Kipling (1983), in discussing cannibalism between age 0 and 1 pike, observed that age 1 pike reached a size of 40 cm by fall and could take prey which were up to 45 per cent of their own length. This meant that young-of-the-year pike which did not attain a length of 18 cm or more would be susceptible to cannibalism. By the end of August, young-of-the-year pike in the Saskeram Marshes have reached an average length of 20 cm or more. Had there been any appreciable numbers of yearling pike within the marshes, most young-of-the-year pike would nevertheless have been too large to be cannibalized. Except for a small percentage of pike, most individuals within the 1983 and 1984 cohorts were relatively uniform in size and did not vary more than approximately 5 cm about the mean size (Fig. 35). Spatial segregation of pike of different sizes may also have been a factor responsible for low level of cannibalism. Chapman and Mackay (1984) noted that large pike (i.e. >25 cm) were more often found in deep unvegetated water than were small pike. The absence of any appreciable degree of cannibalism suggests that young-of-the-year pike had an abundance of prey in the Saskeram Marshes. It has been noted that pike populations will maintain themselves through cannibalism in the absence of sufficient prey species (Munro cited by Kipling 1983).

Results for both years indicated that young-of-the-year pike in the Saskeram Marshes fed more actively during the early part of their growing season. In July and August approximately 70 per cent of the specimens autopsied had consumed food. By September, this ratio decreased to about 40 per cent (Tables 27 and 28). These findings are similar to those of Holland and Huston (1984), who observed that during the spring 96 per cent of young-of-the-year pike had eaten, but by August only 42 per cent contained food. A greater percentage of empty stomachs were observed in the 1984 sample of young-of-the-year pike (57%) than in the 1983 sample (46%).

Based on the frequency of occurrence of food items, especially forage fish, it appears that young pike in the Saskeram Marshes fed better in 1983 than in 1984. Therefore it might be expected that the growth of pike should have been better in 1983 than in 1984. The opposite, however, was true; young pike grew considerably faster in 1984 (Fig. 46). This divergence may have been due to several factors. Firstly, average water temperatures were slightly higher in 1984 than in 1983 during most of July and August (Fig. 56). Frost and Kipling (1968) observed that temperature alone may have a direct effect on the growth of young-of-the-year pike. The higher temperatures may have increased digestive rates in young Saskeram pike thereby contributing to the greater frequency of empty stomachs observed in 1984. Secondly, the young pike were exposed to summerkill conditions early in August, 1983, which undoubtedly curtailed growth in the surviving individuals. Finally, daylight conditions were somewhat better in 1984 than in 1983. The average number of hours of sunshine per month at The Pas for the period May - August was 265.4 h in 1983 and 303.9 h in 1984. Since pike feed by sight, better light conditions would enhance their foraging and consequently growth. For example, Frost and Kipling (1967) reported good growth in pike during a cold, bright September as opposed to poor growth in a cold, dull September.

The growth of young-of-the-year pike in the Saskeram Marshes appears to be unique for that latitude. Comparison of lengths for Saskeram pike with those reported by Koshinsky (1979) for Lac La Ronge pike shows a wide divergence (Fig. 61) even though climatic conditions in the two areas are similar (Longley 1972). Although early growth of pike in the Saskeram Marshes was not documented, it is probably similar to that reported by Hunt and Carbine (1951) for Houghton Lake in Michigan.

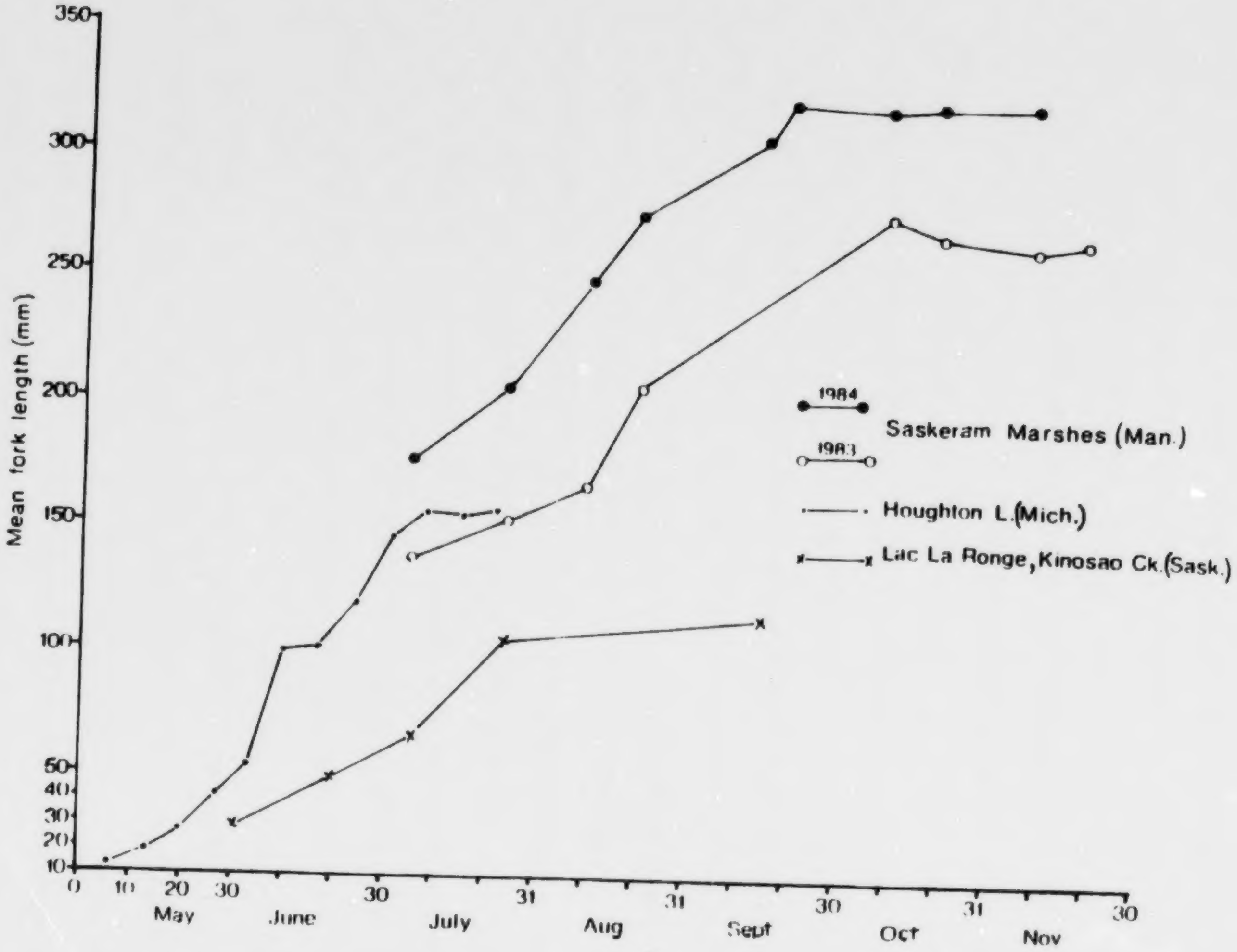

Fig. 61. Comparisons of the growth of young-of-the-year pike in the Saskeram Marshes in 1983 and 1984 with the growth of young-of-the-year pike reported by Koshinsky (1979) for Lac La Ronge and by Hunt and Carbine (1951) for Houghton Lake.

The early growth of Saskeram pike also approximates that reported for young-of-the-year pike in the Lake Dauphin area of Manitoba during 1982 by Gaboury (1985). Young pike in the Lake Dauphin area reached a length of 15 cm by late August. This compares with the average growth of Saskeram pike in 1983, but is almost 10 cm less than the average size attained in 1984. By late October, Lake Dauphin pike were 23 cm long. This was still 2 to 5 cm shorter than the Saskeram pike. Since the Lake Dauphin area is approximately 300 km farther south and has a slightly less severe climate than the Saskeram area, the exceptional growth of pike in the Saskeram Marshes cannot readily be ascribed to climatic conditions. It is rather believed that the unique faster growth of pike in the Saskeram Marshes is related to the greater food resources in those marshes. These food resources were greatly enhanced when the Saskeram Lake area was dewatered and reflooded. This contention is supported by results from Hassler (1969) for pike from Lake Oahe, a Missouri River reservoir. He found that pike in the reservoir grew faster than pike in other areas of the world and attributed the exceptional growth to the uncrowded conditions and abundant food supplies during the early years of impoundment.

The stomach contents observed in adult pike in both 1983 and 1984 revealed that they preyed heavily on leeches and other invertebrates (amphipods and dragonfly nymphs) during their initial period in the Saskeram Marshes (Tables 25 and 26). Since adult pike are primarily piscivorous (e.g. Kipling 1983 and Chapman and Mackay 1984), their selectivity of small invertebrate items appears somewhat unusual. According to Toner and Lawler (1969) and Nursall (1973) the optimal size of prey for adult pike may vary between one quarter and one half the predator's length. The advantage in selecting larger prey lies in the minimization of energy costs in capturing prey. As indicated by Diana (1980), even the rare inclusion of a large prey item may have a significant impact on pike growth. Where the interval between the appearance of large prey items becomes too great, the pike will resort to eating smaller organisms (Hart and Connellan 1984). Evidently populations of other large fish species which occupied the Saskeram Marshes at the same time as pike did not generally provide individuals of suitable prey size. The adult pike were therefore required to select invertebrates and the small forage fish such as sticklebacks. The strong representation of leeches in pike stomachs early in the season was probably because of their proximity to the adult pike and their abundance, conspicuousness and poor swimming ability which made them easy prey for the pike. Since leeches normally inhabit shallow water, their distribution would overlap that of the spawning pike. Sticklebacks and other forage fishes may have become more prevalent in pike stomachs due to the movement of pike into deeper waters within the marsh. The observation of pike cannibalism in 1984 was unique. As noted earlier, this cannibalism was due to the introduction of large pike associated with spilling operations at Cumberland Dam.

The presence of large adult pike in marshes where waterfowl are being produced has been cause for some concern among waterfowl managers. Previous investigations have shown that adult pike may prey on young waterfowl. For example, Solman's (1945) study of pike-waterfowl relationships in the Saskatchewan River Delta downstream of The Pas found that 3 per cent of fed pike had consumed waterfowl. Almost half (45%) of the waterfowl were less than one week old and most (80%) were diving species. In a subsequent study by Lagler (1956), only 0.3 per cent of feeding pike contained waterfowl. This figure agrees with the incidence of waterfowl found in pike stomachs in the Saskeram Marshes; the incidence ranged from 0.2 per cent in 1983 to 0.6 per cent in 1984. The waterfowl noted were a coot and a grebe, whose diving habit would make them vulnerable to pike predation. The predation of pike upon young waterfowl may not be a significant factor in the Saskeram Marshes because of the behaviour of pike. Solman (1945) noted that the earliest date when young waterfowl were seen in pike stomachs was mid-June. By this time most of the adult pike which moved into the Saskeram Marshes have already returned to the Saskatchewan River.

Observations on the monthly feeding patterns of adult pike in 1983 (Table 25) indicated that they began concentrating more on forage fishes in June, although invertebrates were still important. The greater number of feeding pike caught in June (75 percent as opposed to less than 65 per cent in either May or July) suggested intensified feeding during this period. This increased feeding following the spawning period may have been due to the gradually increasing water temperatures (Fig. 56). Weithman and Anderson (1977), observing pike feeding in Missouri, noted that pike food consumption peaked about May 1. At this time water temperatures were between 15° and 20°C and the adult pike were consuming about 100 per cent of their body weight. This coincides with work by Diana (1983) which indicated adult pike achieve their optimal growth at 19° to 21°C. Although the feeding of adult pike in the

Saskeram Marshes was not followed past July in 1983, the small numbers examined indicated that feeding intensity was beginning to abate. Weithman and Anderson (1977) found that food consumption in adult pike fell to only 13 per cent of their body weight by late July. This coincided with a peak in summer water temperatures between 25° and 30°C. Diana (1983) reported that the upper lethal temperature for pike to be 29°C.

The growth of pike sampled from the Saskeram Marshes was compared with the growth of pike from several marsh environments in different areas. In making this comparison, the 1984 data for the Saskeram Marshes were used since they represented the fastest growth observed during the two year study. The areas for which pike growth information was selected from the literature were:

1. The Netley-Libau Marshes which are situated on the south end of Lake Winnipeg and on about the 50th parallel. The pike growth, which was described by ages determined from cleithra, was based on samples collected during the openwater seasons in 1980 and 1981 (Janusz and O'Connor 1985). Age-specific lengths used in this plot are observed lengths at capture.
2. The area of Lac La Ronge surrounding the Kinosao Creek area and situated just north of the 55th parallel. (Saskeram Marshes are located exactly on the 54th parallel) The growth in this case was based on scale ages for pike samples collected in 1967 (Koshinsky 1979). Age-specific lengths were presented as back-calculated lengths in this instance.

3. The St. Louis River estuary at the western end of Lake Superior and situated at approximately the 47th parallel. The growth is based on 1979 samples and ages were determined from scales (Schram 1983). Age-specific lengths are also back-calculated lengths.

Also used in the comparison is the average growth curve determined for pike throughout the United Kingdom as reported by Hickley and Sutton (1984). Comparisons of the above growth curves to the growth curve for Saskeram pike in 1984 are given in Figure 62.

The comparison of growth curves in Figure 62 again underlines the phenomenal growth experienced by Saskeram pike during their first two years of life and particularly during their first summer. The possible factors responsible for this rapid initial growth were examined earlier in the text (page 194). This growth rate, however, was not sustained after the pike reached maturity. After age 2, the average length of pike in the Saskeram Marshes was similar to those reported elsewhere. Although Saskeram pike began maturing earlier, the most common age at first maturity, as indicated by the age frequency distributions in the spawning run (Fig. 32), was age 2. The growth of older pike (>age 4) from the Saskeram Marshes was closely similar to that reported for the Netley-Libau Marshes and Lac La Ronge, but was considerably less than the growth reported for the U.K. or for more southerly populations in North America (e.g. St. Louis River estuary). The growth of mature Saskeram pike, which is similar to Lac La Ronge pike, is perhaps typical of the northern populations. R. P. Johnson, cited by Koshinsky (1979) found that pike from a lake near Lake Athabasca grew at the same rate as pike in Hunter Bay, Lac La Ronge.

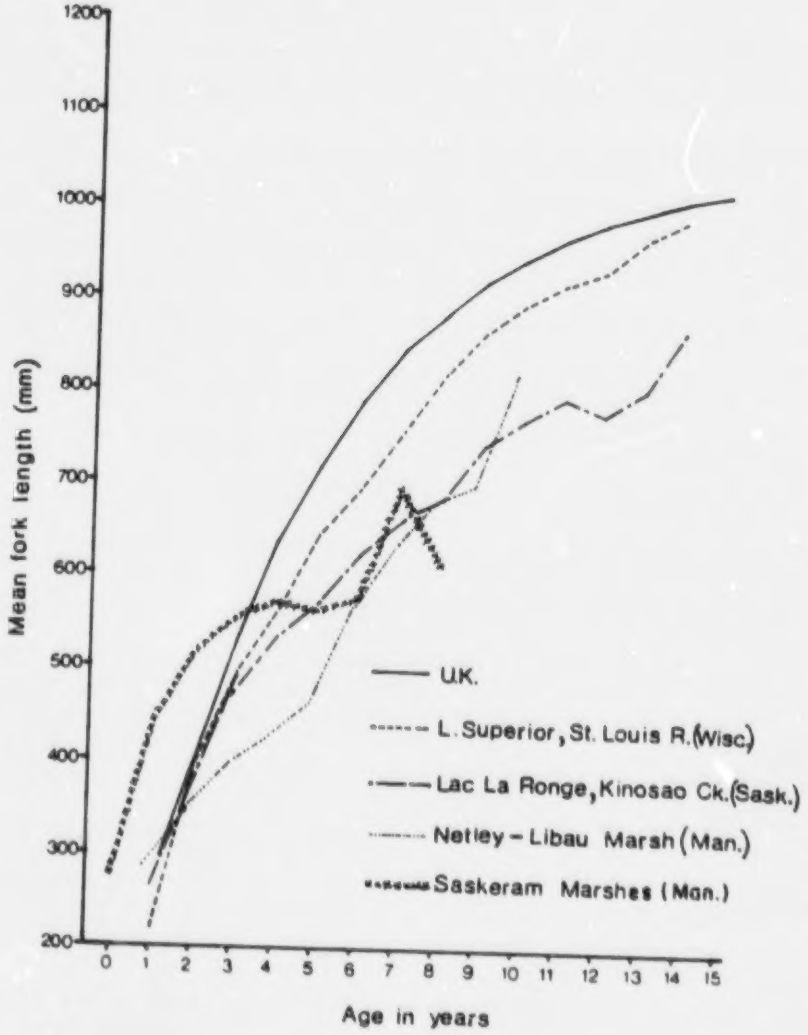

Fig. 62. Comparison of pike growth in the Saskeram Marshes with pike growth reported for Netley-Libau Marshes in Manitoba (Janusz and O'Connor 1985), Lac La Ronge in Saskatchewan (Koshinsky 1979), the St. Louis River in Wisconsin (Schram 1983) and with the standard growth curve for pike in the United Kingdom (Hickley and Sutton 1984) .

Further information on the growth of Saskeram pike was provided by comparing the lengths of tagged pike at the time of release and recapture. These comparisons indicated that the incremental growth over a year's time (i.e. 270 to 450 days) varied from less than 0.01 mm to 0.3 mm/day and averaged 0.10 mm/day (Appendix XXIII). These increments may be higher if it is assumed that growth is achieved only during the ice-free or "growing" season. However, Diana and Mackay (1979) found that pike in central Alberta grew almost as much during the winter as they did in summer. Further studies by Diana (1983) demonstrated that winter growth is a common characteristic of pike. Diana (1983) also observed that there was no relationship between total growth of pike and the length of the ice-free season. This observation was based upon pike populations in lakes located between the 42nd and 46th parallels of latitude. Harrison and Hadley (1983) reported that growth of pike in the Niagara River watershed in New York resembled that of pike from northern Wisconsin and Saskatchewan. Miller and Kennedy (1948), on the other hand, found that growth and maturation rates of pike did vary over 19 degrees of latitude, A comparison of the daily length increments of Saskeram pike to those for pike from Houghton Lake in Michigan reveals no significant difference in growth rates. Houghton Lake is located near the 44th parallel; 10 degrees of latitude south of the Saskeram Marshes. Carbine and Applegate (1946) found that over approximately a year's time, tagged pike in Houghton Lake achieved daily length increments which varied from 0.02 mm to 0.44 mm/day with an average of 0.13 mm/day. These results are virtually the same as those noted above for Saskeram pike. It is doubtful that the growth of the tagged fish was significantly altered by the tagging process or the tag itself. Koshinsky (1979) noted only a slight detrimental effect of tagging upon pike growth and this effect was primarily seen among the smallest fish. The above comparisons would suggest that the growth rate of mature Saskeram pike does not appreciably differ from the growth rates among more southerly populations.

The average condition factor of Saskeram pike was 0.77 in both 1983 and 1984 (Appendices XIa and XIIa). This compares with the condition factors observed for Notigi and Wapisu lakes, two flooded lakes on the Rat River in northern Manitoba (Patalas 1984). The condition factor for Saskeram pike is higher than those reported for pike populations in the Cross Lake area of the Nelson River (Gaboury and Patalas 1982) or in two Precambrian Shield lakes east of Lake Winnipeg (Hagenson 1984). Condition factors for pike observed in these studies varied between 0.64 and 0.67.

The total mortality of adult Saskeram pike derived from the total catch data for 1983 and 1984 varied from 49 to 75 per cent (Table 21). The average total mortality rate was perhaps somewhere between 60 and 65 per cent. This rate appears to agree with the average total mortality rates reported for exploited pike populations. For example, Groebner (1964) noted an average total mortality rate of 65 per cent for pike in Minnesota, while Snow and Beard (1972) reported an average rate of 65 per cent for Wisconsin pike. In both these studies, the annual mortality rates varied from roughly 35 to 90 per cent. Koshinsky (1979) observed a similar mortality rate (61%) for pike populations in the more accessible, and heavily fished parts of Lac La Ronge. In remote areas of the lake where little fishing occurred, he found a total mortality rate of only 19 per cent. This rate is low; other investigators have found total mortality rates which typically average around 40 per cent for moderately or lightly exploited pike populations. For example, Wolfert and Miller (1978) determined rates of 38 to 44 per cent for Lake Erie pike. Pike in Lake Erie are probably widely dispersed and subject to little fishing mortality. Total mortality rates determined by Lysack (1982) for 17 remote lightly fished lakes in morthern Manitoba ranged from 12 to 65 per cent and averaged 42 per cent. Schram (1983) noted a similar total mortality rate (45%) for pike in a Lake Superior estuary. These lower mortality rates approximate the natural mortality rates of pike populations under unexploited conditions. Casselman, cited by Payne _et al_. (1983), indicates that the natural mortality rate of northern pike presumably from Ontario waters is around 45 per cent. This is somewhat lower then the 55 to 60 per cent range Snow (1978) reported as the natural mortality of pike (>356 mm) in the absence of angling. In some cases, natural mortality in pike may be even higher. Snow (1974) observed that the natural mortality rate of native pike in the Murphy Flowage in Wisconsin increased from 21 per cent to 86 per cent between 1963 and 1964. He attributed this increase to the 1964 introduction of stocked pike which were infected with a protozoan parasite, _Myxobolus_ sp.. Except for a moderate incidence of blackspot (_Neascus_ sp.) in 1984, no major epizootic or parasitic infection, which might have caused some natural mortality, was evident in the Saskeram pike. The total mortality rate of Saskeram pike (60 - 65%) falls within the range of rates which Payne _et al_. (1983) indicate as bordering on high risk of overexploitation.

This suggests that Saskeram pike are subject to heavy exploitation from both commercial fishermen and anglers fishing in various parts of the Saskatchewan River Delta.

The density of juvenile pike (>200 mm in fork length) in the Saskeram Lake area, as estimated by the numbers caught leaving the marshes, varied from 4.2 and 11.4 individuals per hectare (Table 33), depending on water levels and the area flooded. It must be recognized that these densities may not be totally ascribed to the Saskeram Lake area, as an unknown quantity of young-of-the-year pike was recruited from the Cumberland Marshes in 1984. It is difficult to compare the above densities with those documented in other investigations. Such comparisons are thwarted because of several or more factors. First, most areas for which densities of juvenile pike have been described are small (<5 ha), controlled pike spawning or rearing marshes. Since such areas can be easily drained, it is possible to account for virtually every individual produced. Because of the size of the Saskeram Marshes and because fall discharges from them are reduced to assure overwintering of muskrats, it is doubtful that all juvenile pike produced in the marshes are able to escape before freeze-up. The observed escapement is therefore, at best, only a rough estimate of pike densities, or productive potential, in the Saskeram Marshes. Secondly, the small managed pike marshes are probably used to their maximum capacity. The Saskeram Marshes were not used to their maximum extent by pike during 1983 and 1984. If the numbers of spawners entering the marshes had been the same as those observed by Leroux (1982) in 1981, subsequent densities of juvenile pike would have been much higher. Thirdly, young-of-the-year pike are usually released from managed marshes before they have achieved their maximum growth. At this stage, natural mortality factors such as predation, cannibalism, starvation, disease and parasitism, etc. have not been present long enough to substantially reduce the cohort. Fourthly, the various studies range in time and therefore productivity levels reported have been influenced by differing environmental conditions. Fifth, comparisons with studies that have reported pike productivity in natural waters are confounded since there is often no distinction made between the non-productive portions of the waterbodies and those habitats which are productive of pike. Finally, many studies on pike production have not provided detailed information on the water quality or biological characteristics of the waterbody; these factors should accompany any comparisions of fish production (Chapman 1966). While recognizing the above limitations, an effort was nonetheless made to compare the densities of pike in the Saskeram Lake area with densities reported by other investigators. In making these comparisons, consideration was only given to the size of pike produced, the area of the waterbody in which they were produced and whether the waterbody was natural or managed (Table 36).

The data presented in Table 36 suggest that even in small, highly managed pike spawning marshes or rearing areas, densities may vary considerably. Fago (1977), who examined pike fry and fingerling production from managed waters in six U.S. states, made a similar observation. At first inspection of Table 36, it appears that the density of pike in the Saskeram Lake area is similar to densities reported by Cooper for a 73 ha lake in Michigan and by Lawler for Heming

Table 36. Densities (no./ha) of pike fry (≤50 mm), fingerlings (<100 mm) and larger individuals produced from small managed pike marshes in various states and one province and from several unregulated waterbodies compared to the Saskeram Lake area in 1983 and 1984.

Location of Waterbody	Av. or range in production (no./ha)	Av. size of pike (mm)	Source Reference
Creek in the Sask. R. Delta Manitoba [3]	66.7	>356	Solman (1945)
4 ponds(≤1 ha) in Nebraska [1]	5496	51	McCarraher (1957)
10 pike spawning marshes in Michigan [1]	1900-10,664	76-102	Di Angelo & Williams (1962)
73 ha lake in Michigan [3]	12.6	>356	Cooper (1951) cited by Groebner (1964)
3.6 ha marsh in Minnesota [1]	5881.4	fingerlings (~70)	Groebner (1964)
3.0 ha marsh in New York [1]	14,449 6,319	~36 ~46	Forney (1968)
4.0 ha marsh in Wisconsin [1]	18-173	~53	Kleinert (1970)
2.6 ha marsh in S. Sask. [1]	3367	77	Royer (1971)
2.0 ha marsh in Michigan [1]	42	74	Beyerle & Williams (1972)
1.5 ha marsh in Wisconsin [1]	131-1312	71-99	Fago (1977)
7.5 ha marsh in Wisconsin [1]	276-426	97-109	Fago (1977)
58 ha reservoir in Czechoslovakia [2]	2.7	All ages	Holcik (1977)
Heming Lake (259 ha) in Manitoba [3]	14.8	>380	Lawler, cited by Koshinsky (1979)
River Frome England [3]	45-229	age 0+	Mann (1980)
Saskeram Lake [4]	4.2-11.4	218-274	Present study

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[1] Marshes managed for pike production
[2] Reservoir with fluctuating water levels
[3] Unregulated or natural waterbody
[4] Water levels managed for waterfowl and muskrat production

Lake, a 259 ha lake lying on the Precambrian Shield north of The Pas. Since the pike considered by both Cooper and Lawler were primarily mature fish (>350 mm), the associated numbers probably represent a much higher density if they are equated to size ranges similar to those for Saskeram pike. For most marshes from which pike are released as small fish (i.e. ≤100 mm in length), densities which exceed 100 fish/ha and may even be higher than 10,000/ha, have generally been reported (Table 36). Densities of less than 100/ha, as reported by Kleinert (1970), Beyerle and Williams (1972) and Fago (1977), appear to be the exception for small rearing areas. The information presented by Beyerle and Williams (1972) is noteworthy; they found that of the 42/ha released as fingerlings, 11.4/ha survived into the fall. This is the same as the upper range of pike densities for the Saskeram Lake area. The density (2.7/ha) reported by Holčík (1977) for a small reservoir in Czechoslovakia is much smaller than that found for Saskeram Marsh. Holčík, however, found a much higher density (8.7 pike/ha) two years after the reservoir was flooded. When the reservoir reached an equilibrium state about 10 years after flooding, the density of pike fell below 2/ha. The preceding comparisons with Saskeram Lake are inconclusive because of the inconsistencies in the way in which results are reported by the various investigators. In general it would appear, however, that the pike densities determined for Saskeram Lake fall within the range of expected density values; they are perhaps at the lower end of the range.

Another approach to comparing the pike productivity of the Saskeram Lake area, assuming no recruitment from the Cumberland Marshes, with other waters is to examine biomass (i.e. standing crop) and production values per unit area. Biomass or standing crop ($\overline{B}$) is an estimate of the total ichthyomass in an area at a specific moment in time. Production (P), as defined by Chapman (1966, 1978), is the total elaboration of new fish flesh by a species population during a specified time period. Production is generally greater than biomass for a cohort during its first and second year of life, after which biomass exceeds production. In the younger age groups most of the food intake is used for new growth, while in the older age groups more is devoted to body maintenance. Biomass and/or production values reported for pike from a number of waters in the United States and United Kingdom, as well as Lac La Ronge in Saskatchewan, and the Netley-Libau Marshes in Manitoba are presented in Table 37, along with production values for the Saskeram Lake area. It sould be noted that the biomass yields of young-of-the- year and yearling pike reported from a number of U.S. waters and from Saskeram Lake are considered as production in the previously defined sense. This assumption seems valid since a) the yields represent the total biomass accrued in the waterbody from the time of spawning to the time of release and b) the yields generally agree with actual production values calculated for pike by investigators in the U.K. With these considerations, the productivity of Saskeram Lake for underyearling pike approaches the lower range productivity levels reported for young-of-the-year pike from small marshes in New York (Forney 1968) and Wisconsin (Fago 1977) and from the River Frome in the U.K. (Mann 1980). The value presented by Mann (1980) for age 1 and older pike (51.5 kg/ha/yr - Table 37) represents a 10 - fold increase over the production of the pike during their first year of life. If this factor is applied

Table 37. Biomass and production values reported for northern pike in various waters in the U.S.A., Europe and Canada compared to Saskeram Lake.

	Biomass (kg/ha)	Production (kg/ha/yr)	Size or age group	Locale	Source Reference
U.S.A.	9.0	-	mature pike	All U.S. Waters	Carlander (1955) (Cited by Koshinsky 1979)
	16.8-27.9	-	mature pike	Murphy Flowage, Wisconsin	Threinen *et al.* (1966) (Cited by Koshinsky 1979)
	-	3.6-7.6 [1]	o+ fingerlings	Marsh off Oneida L., New York	Forney (1968)
	-	14.6 [1]	o+	Laura L., Minnesota	Johnson and Moyle (1969)
	-	24.7 [1]	1+	Laura L., Minnesota	Ibid.
	-	13.5-96.4 (42.8) [2]	o+ (~50 days old)	0.4 ha ponds, Nebraska	Howard and Thomas (1970)
	27.3	-	>254 mm	Bucks L., Wisconsin	Snow and Beard (1972)
	-	2.5-18.0 [1]	o+ fingerlings	Pleasant L. & Pabst Marshes, Wisc..	Fago (1977)
	14.7	-	>356 mm TL.	Murphy Flowage, Wisconsin	Snow (1978)
Europe	10.4-19.5	4.0-5.1	mature pike	Lake Windermere, U.K.	Johnson (1966)
	-	4.2-18.9	1+ and older	Lake Windermere, U.K.	Kipling and Frost (1970)
	1.4	5.0 [6]	o+ (>55 mm)	River Frome, U.K.	Mann (1980)
	70.9	51.5	1+ and older	River Frome, U.K.	Ibid.
	45.8	26.1	1+ and older	River Stour, U.K.	Ibid.
	4.4-50.3 [3] (16.2) [2]	-	0+	4 shallow waters, Netherlands	Grimm (1981)
	68.4	41.3	1+ and older	River Frome, U.K.	Mann (1982)
Canada	26.9 [4]	-	all ages	Lac La Ronge, Saskatchewan	Koshinsky (1979)
	23.2-32.0 [5]	-	all ages	Netley Libau Marshes, Manitoba	Janusz and O'Connor (1985)
		0.54-2.27	o+ (>100 mm FL)	Saskeram Lake, Manitoba	Present study

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[1] Biomass estimate assumed to be equivalent to production. Other production estimates are estimates of new tissue growth.

[2] Mean biomass or production.

[3] Based on effective (vegetated) pike habitat.

[4] Based on area between 0 and 10 m.

[5] Estimate derived from an estimate of potential fish standing crop (all species) based on total phosphorus and from the percentage contribution of northern pike to standard-gang gillnet catches in Netley-Libau Marshes.

[6] Production calculated for o+ pike from June 1 to the following March.

to pike orginating from Saskeram Lake, then the production of age 1 and older pike from the area would range in the order of 5.4 to 22.7 kg/ha/yr. At best, this is an order-of-magnitude estimate of the potential production of pike from the Saskeram Lake area. It does, however, compare favourably with range in production (4.2 to 18.9 kg/ha/yr) reported by Kipling and Frost (1970) for Lake Windermere in the U.K.. Mann (1980) indicates that the relationship between production and biomass (i.e. turnover or $P/\bar{B}$ ratio) may be constant for any given species and presents $P/\bar{B}$ ratios for pike from a range of habitats. The average of these $P/\bar{B}$ ratios for age 1 and older pike is 0.57. Applying this turnover ratio to the estimated production of age 1 and older pike for the Saskeram Lake area, the estimated biomass values range from 9.5 to 39.8 kg/ha. This range falls within the range of other biomass values presented in Table 37. The upper end of the biomass range for Saskeram (39.8 kg/ha) is even slightly better than pike biomass levels reported for U.S. or Canadian waters. Significantly higher pike biomass levels have been observed for streams in the U.K. (Mann 1980, 1982). This difference is because lotic environments are typically more productive of fish than are lentic environments (Chapman 1978).

A further estimate of the productivity or suitability of the Saskeram Marshes for pike may be derived from a comparison of pike in the marsh at various stages with survival rates determined in other studies. A theoretical survival curve for young-of-the-year pike in the Saskeram Marshes from spawning to total emigration at freeze-up is presented in Figure 63. This survival curve is based only on the estimated egg deposition in 1983; as indicated earlier the data for 1984 was not used because of the supplemental contribution of young pike from the Cut Beaver area of the Cumberland Marshes. The survival curve in Figure 63 is based on the division of mortality into three different stages. These stages are:

1. The egg-prolarval stage or the period between egg deposition and when the pike larvae become free-swimming.
2. the postlarval - fry stage or the period of time between the onset of active feeding to attainment of fingerling size (~70mm) and
3. the post-fingerling stage or the period between the time when young pike begin leaving the marshes to freeze-up or the conclusion of emigration.

The following mortality rates were applied to each of the stages:

Stage 1 - 95 per cent

Stage 2 - 90 per cent

Stage 3 - 20 per cent/month

These mortality rates, although purely arbitrary, are approximate in their order of magnitude to mortality rates reported by other investigators for pike during their early life stages. The time periods during which these mortality rates are in effect are also approximate. It is believed peak spawning activity in 1983 occurred about the third week of May. It is not known when hatching occurred in 1983. However, since water temperatures increased constantly during the spawning - incubation period and were near optimum, it is believed that hatching

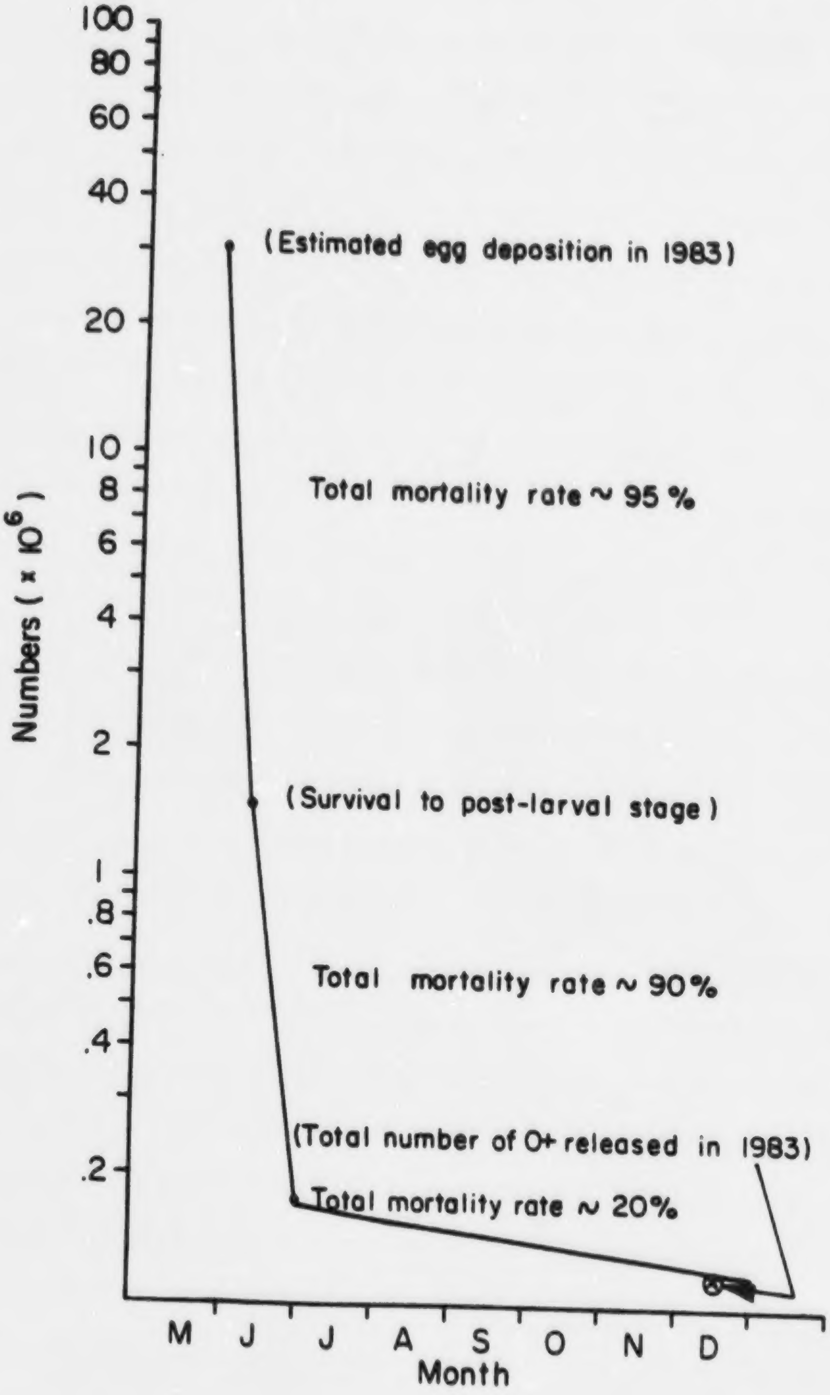

Fig. 63. A hypothetical survival curve for northern pike in the Saskeram Marshes from the egg stage to emigration in 1983. Note that the scale on the y - axis is logarithmic. (See text for further explanation.)

occurred within two weeks of peak spawning and that the young pike were free-swimming within another 7 to 10 days. Stage 1 therefore probably extended from the third week of May to approximately the middle of June. Although we were unable to measure the very early growth of pike in the Saskeram Marshes, a projection of the 1983 growth curve of underyearling pike (Fig. 61) backward suggested pike reached fingerling size by about the end of June. Stage 2 therefore may have encompassed the time period from about mid-June to early July. Fingerling pike began leaving the Saskeram Marshes by the second week of July in 1983 and continued to leave in varying numbers until December (Fig. 26). This period represents Stage 3. The derived survival curve provides a projected release at freeze-up (mid-December) of approximately 40,000. This estimate is similar to the estimated 35,000 to 45,000 or the actual total count (34,753) of young pike released from Saskeram Marsh in 1983. Although the survival curve is strictly hypothetical, it does provide a plausible depiction of mortality events among young-of-the-year pike in the Saskeram Marshes.

Based on the above mortality rates, survival of young pike in the Saskeram Marshes is similar to or perhaps slightly better than what has been reported elsewhere. As indicated earlier (page 187), the approximate survival rate of Saskeram pike from egg disposition to mid-December was 0.1 per cent. Johnson and Moyle (1969) reported a maximum survival rate from eggs to harvested pike (young-of-the-year or yearling) of 0.1 per cent. This survival rate is twice the rate found for young pike in Irish lakes during roughly the same length of time; Doyle, cited by Mann (1980), found survival rates of 0.04 to 0.07 per cent from the egg to 5 or 6 months later. Carbine (1944) reported rates ranging from 0.04 to 0.44 per cent for pike survival from the egg to the 200 mm length stage. Saskeram pike achieved a mean fork length of 200 mm by September in 1983. The projected survivorship at this stage, as estimated from the survival curve, would have been 76,800. This represents a survival rate of 0.26 per cent which falls within the upper end of the range reported by Carbine (1944). The curve estimated survival rate of Saskeram pike between spawning and the fingerling (50-70mm) stage was 0.5 per cent. This is substantially better than the 0.06 per cent survival rate reported by Koshinsky (1979) for pike from a Lac La Ronge spawning area and is contained within the range of survival rates noted by Franklin and Smith (1963) and Fago (1977). Fago (1977), who studied the survival of pike in two small rearing marshes for 2 to 5 years, found survival rates from the egg to fingerling stage which ranged between 0.15 and 2.69 per cent; almost three-fourths of the survival rates were less than 1.0 per cent. Franklin and Smith (1963) reported survival rates over a similar time period of 0.08 and 4.62 per cent in a partially controlled pike rearing marsh. The Saskeram results also compare favourably with those of Jarvenpa (1962). If the exceptionally high surviva's are deleted, the average of the egg to fingerling survival rates reported by Jarvenpa (1962) for a number of pike rearing areas in Minnesota is 0.51 per cent. Forney's (1968) results indicated slightly better survival rates (2.8 - 4.1%) for pike produced in a small rearing marsh off Oneida Lake. However, in this instance the pike were released at a slightly earlier stage;i.e. when they had reached average lengths of about 35 to 45 mm. Survival to the end of the postlarval stage (Stage 1) in the Saskeram Marshes was projected to be about 5 percent. This is substantially better than the 0.9 per cent survival rate reported by Montén, as cited by Toner and Lawler (1969) or the 0.5 to 2.3 per cent range stated by Mann (1980) for the period from egg deposition to just after hatch. The application of a 20 per cent monthly mortality rate for fingerling pike over the remainder of the openwater period (Stage 3) appears valid. This monthly rate equates to a 26.2 per cent survival rate over the season. This rate is similar to the results of Beyerle and Williams (1972) who found a mean annual survival rate, over three years, of 28 per cent for fingerling pike through the fall of their first year. Mann (1980) stated that the survival rate among underyearling pike after the fingerling stage may be similar to that found among adult pike. Survival rates for adult Saskeram pike varied between 25 and 50 per cent, depending on the method of estimation used (Table 21); generally, survival rates appear to be closer to the 30 per cent level. Survival rates among underyearling pike can, however, be higher. Mann (1980) reported a 62 per cent survival rate for pike between the fingerling stage and the end of their first winter, while Beyerle and Williams (1972) observed a 66 per cent fall survival of fingerling pike in one year.

From the above considerations, we suggest that the survival curve, as presented in Figure 63, provides a reasonable approximation of events in the early life history of northern pike in the Saskeram Marshes in 1983 and a generalization of the productive capacity of the general area for pike. Most of the above comparisons are with generally smaller, more regulated areas in the more southerly latitudes (e.g. Minnesota, Wisconsin, Michigan, New York, etc.) where one might expect more favourable weather conditions for pike reproduction and survival. The fact that early survival of pike in the Saskeram Marshes is as good, and perhaps better than elsewhere, indicates their suitability for pike production.

Despite the suitability of the Saskeram Marshes for the production of pike, limitations on their productive capacity may be imposed by the occurrence of summerkill and winterkill conditions. Although continuous, long-term and detailed information is not available, occasional previous observations suggest that both events occur with some regularity on the Saskeram Marshes.

Summerkills are typical of highly productive waters and may result in partial or total fish die-offs (Lawler et al. 1974). Summerkills of pike may be precipitated by high temperatures alone. For example, Krohn (1969) reported a mid-August die-off of pike in a Wisconsin lake following several warm days when water temperatures ranged from 32°C at the surface to 24 °C at a depth of 3.7 m, the lower limit of oxygenated water. Similarly, Goddard and Redmond (1978) found that surface temperatures of 32°C coincided with the beginnings of a pike die-off in a Missouri lake. The main cause of mortality in both cases was evidently temperature, since it exceeded the upper incipient lethal level (29.4°C) which has been recorded for northern pike (Casselman 1978). Since water temperatures in the present study did not reach the upper lethal level in either year high, temperature cannot be implicated as the sole cause of the summerkill in the Saskeram Marshes in 1983.

Comparison of observations on the 1983 summerkill in the Saskeram Marshes with those reported by Casselman (1978) for a number of different studies (Fig. 55) indicated that low dissolved oxygen concentrations in combination with high water temperatures, as well as perhaps very rapid and marked temperature changes, were primarily responsible for the pike die-off. The low oxygen conditions in the Saskeram Marshes were probably attributable, in part, to submergent plant growth in the marsh. Certainly, growth of aquatic macrophytes had reached its maximum in the marsh by early August. Submergent plant growth in the openwater channels in Saskeram Lake had reached a point by mid-summer where travel by outboard motorboat was virtually impossible. These high plant densities could have led to oxygen depletion. Although dissolved oxygen was routinely measured only in the lower Birch River, the horizontal oxygen gradient found in the river in 1983 suggested some oygen depletion may have been occurring in Saskeram Lake (Fig. 54). This conclusion is corroborated by the ratios of live and dead young-of-the-year pike in traps at Bracken Dam and the trap set in the channels in Saskeram Lake. During the summerkill period, 38 per cent of the pike caught at the dam were dead, while 53 per cent of the catches in the lake were dead (Table 31). This conclusion is also supported by the work by Casselman (1978) who reported critically low summer oxygen concentrations and the onset of mortality among young of-the-year pike in drainage ditches that were clogged with submergent plants such as _Elodea_, _Myriophyllum_ and _Ceratophyllum_. Oxygen depletion caused by submergent plants has been discussed by Buscemi (1958). He found dissolved oxygen levels as low as 0.4 mg.l^{-1} at the bottom of a stand of _Elodea canadensis_. Casselman (1978) noted that the low oxygen conditions were coincident with a period of overcast skies. This suggests that the aquatic plants were respiring and using up oxygen rather than photosynthesizing, thereby producing oxygen. This is in contrast to observations in the present study; the 1983 summerkill coincided with a period of bright, sunny weather. However, wind conditions were calm. Prolonged periods of calm weather may lead to stagnation, which reduces absorption of atmospheric oxygen and consequently increases the severity of oxygen depletion (Moore 1942). Since large amounts of oxygen are used up by the respiration of plants at night (Wetzel 1975), the lethal oxygen levels may have occurred at night.

Other factors may also contribute to a summerkill. Doudoroff (1957) noted that extremes in pH, high carbon dioxide tensions and certain toxic substances, as well as high temperatures, can substantially increase the susceptability of fish to dissolved oxygen deficiency. Another situation that has been known for some time to give rise to a summer fishkill is the decay of an extensive algal bloom (Moore 1942). In some instances, the toxins produced by decaying blue-green algae may reach sufficiently high concentrations to be lethal to fish (Mackenthun *et al*. 1945). More recent studies (e.g. Barica 1975 and Ayles *et al*. 1976) indicate that it is the depletion of oxygen subsequent to the sudden collapse and decomposition of an algal bloom which is the principal factor in summer fishkills. Ayles *et al*. (1976), however, speculate that levels of algal toxins, ammonia or temperatures, while they may not be singularly lethal, could act synergistically with low oxygen levels to produce fish mortality. Barica (1975) also notes that ammonia released during the summerkill period may reach toxic concentrations and contribute to fish mortalities if there is only partial oxygen depletion. The above factors did not appear to have contributed to the summerkill of pike in the Saskeram Marshes in 1983.

pH levels although variable, were not extreme and ammonia levels did not approach lethal limits (Crosley 1985). Neither the toxins nor the since depletion of oxygen associated with an algal bloom collapse were involved since there was no evidence of any extensive algal blooms in the marshes. In fact, it is doubtful that dissolved nutrient levels in the marsh were sufficient to generate any major algal blooms. By late summer, most of the nutrients would be bound up in the lush growth of emergent and submergent plants.

The 1983 summerkill of pike in the Saskeram Marshes was only a partial kill; this is evident from the large escapement of young-of-the-year pike from the marsh later in the season. Parts of the marshes, therefore, must have still been suitable for the survival of pike. As speculated earlier, oxygen deficit conditions may have been generated by the respiration of submergent plants in the openwater areas. Whether higher oxygen levels may have been present in the deeper water areas with emergent plant growth and provided a temporary refugium during the brief summerkill periods are not known.[1]

Factors such as high productivity and shallow depths which subject the Saskeram Marshes to summerkill conditions also predispose it to winterkills. It has been shown that winterkills may occur consistently in eutrophic lakes with mean depths of 4.3 m or less (Sain 1983). The only areas in the Saskeram Marshes where depths approaching 4 m may be found are in the upper Birch River near Cumberland Dam and the lower Birch River upstream of Bracken Dam. The remaining areas of the marsh are believed to be so shallow that they freeze either completely to the bottom or to the point where what little water is left beneath the ice is devoid of oxygen and contains high levels of toxic gases. Despite these conditions, various fish species do survive overwinter in the marshes.

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[1] J. Gee (personal communication) noted that dissolved oxygen levels among stands of emergent vegetation in Delta Marsh dropped to zero at night.

Overwinter survival of fish in the Sakeram Marshes is evidenced by the large swarms of brook sticklebacks and fathead minnows which are seen in or leaving the area each year. Since neither species has been seen moving through the Bracken Dam fish ladder into the marshes, they could only have been produced within the Saskeram Marshes or recruited from the Cumberland Marshes. Both the brook stickleback and the fathead minnow are highly adapted to surviving hypoxic conditions; only the central mudminnow, a facultative air-breather which occurs in small numbers in the Saskeram Marshes, is more highly adapted (Klinger _et al_. 1982). Klinger _et al_. (1982) observed brook sticklebacks and fathead minnows surviving in a winterkill lake where dissolved oxygen levels throughout the lake were generally less than 0.3 $mg.l^{-1}$. They found that gas bubbles just beneath the ice, in part, enabled these species to survive and that the gas bubbles found near active muskrat dens were particularly high in oxygen. The Saskeram Marshes have a very large population of muskrats, which may provide oxygenated habitat for sticklebacks and fatheads in the winter. These species may also be overwintering in other parts of the marshes. The observation of large numbers of winterkilled sticklebacks and fathead minnows around control structures in the marsh would suggest some degree of overwinter survival may occur in these areas when flows are adequate to maintain sufficiant oxygen levels. Some may also survive the winter in deeper portions of the Birch River.

The overwinter survival of larger fishes in the Saskeram Marshes appears to be possible in some years. The monitoring of fish movements into and within the marshes in 1983 indicated that substantial numbers of northern pike and white suckers had overwintered in there. Of the two species, pike appear to have a much higher tolerance to low oxygen than do white suckers (Doudoroff and Shumway 1970). It is well known that pike are capable of surviving very severe winterkill. conditions. For example, Koshinsky (1979) noted that a young pike had overwintered in Kinosao Creek, a shallow, marshy tributary which pike from Lac La Ronge used for spawning. Koshinsky indicated that this area froze solid and had no flows during the winter. Cooper and Washburn (1949) observed that pike are able to tolerate oxygen concentrations as low as 0.4 to 0.2 $mg.l^{-1}$. These results are similar to those of Casselman (1978), who reported that pike can survive winter oxygen concentrations as low as 0.3 $mg.l^{-1}$ (or 2% air saturation). Based on information presented by Johnson and Moyle (1969), Casselman determined that complete winterkills of pike in Minnesota lakes occurred at a concentration of 0.21 ± 0.06 $mg.l^{-1}$, while partial winterkills were associated with a concentration of 0.85 ± 0.26 $mg.l^{-1}$. Casselman (1978) also stated that he caught live pike in concentrations as low as 0.04 $mg.l^{-1}$, which suggest that some individuals may be better adapted to survival in low oxygen conditions. The behavioural and physiological adaptations of northern pike to winter hypoxic conditions have been discussed by Magnuson and Karlen (1970), Petrosky and Magnuson (1973) and Casselman and Harvey (1975), as well as by Casselman (1978).

Wintertime dissolved oxygen concentrations near or above 0.85 $mg.l^{-1}$, the level at which partial fishkills may occur, were recorded in the Saskeram Marshes (Appendix XXXIII). These concentrations were encountered most consistently just downstream of the Cumberland Dam. For example, concentrations of 0.6 $mg.l^{-1}$ were recorded below Cumberland Dam in mid-February and early April, 1982. Crosley (1985) reported a concentration of 6.4 $mg.l^{-1}$ in February of the same year. If oxygen levels remained at or above 0.6 $mg.l^{-1}$ through March, then it could be assumed that only a partial fishkill occurred in the area in the 1981/82 winter season. However, one investigator who was monitoring oxygen levels in the area at the time reported that a complete winterkill was apparent. In the 1982/83 season, oxygen concentrations of 4.5 and 8.3 $mg.l^{-1}$ were reported in the Birch River below Cumberland Dam in January and March, respectively (Crosley 1985). These exceptionally high wintertime levels explain the large numbers of untagged pike and white suckers which we encountered in May and June, 1983 and which could only have come from somewhere inside the Saskeram Marshes. Oxygen concentrations well above 1.0 $mg.l^{-1}$ were frequently recorded in the Cumberland Dam area in the 1983/84 and 1984/85 winter seasons. No "strange" fish or fish whose origin could not be easily accounted for, were encountered in 1984 which would have suggested that some fish had overwintered in the Saskeram Marshes during the 1983/84 season. Observations made on February 20, 1985 (Appendix XXXIIIf) indicated a rather large reservoir of well oxygenated water in the Birch River below Cumberland Dam. It is not known whether this area is subject to the same process of winter oxygen depletion as discussed by Barica and Mathias

(1979), Mathias and Barica (1980) and Barica et al. (1983). It has been stated that winter travel on the upper Birch River near Cumberland Dam is inadvisable because of thin ice conditions created by spring activity (D. Leroux, personal communication). Groundwater or spring inflows,if sufficiently oxygenated, could account for the high oxygen concentrations below Cumberland Dam. It has also been speculated that seepage flows through the Cumberland Dam may recharge the oxygen levels in the Birch River. In February, 1985 and oxygen concentration of 5.6 $mg.l^{-1}$ was recorded in the openwater immediately below the dam.

Late winter oxygen concentrations of 0.3 $mg.l^{-1}$ tended to be the normal situation throughout most of the Saskeram Marshes. These concentrations were even prevalent in the lower Birch River, even though it is a sizable body of relatively deep water. Based on observations of oxygen concentrations in the lower Birch River in 1984 (Appendix XXXI), oxygen depletion in this portion of the river proceeds at approximately the same rate as in the upstream area of Saskeram Lake. Oxygen in the lower Birch River appears to be totally depleted in most years, creating complete winterkills. The absence of any overwinter survival of fish in the lower Birch River is further supported by the fact that a gillnet which remained in the river throughout most of the 1983/84 winter season did not contain any fish or fish remains.

From the preceding discussion it may be speculated that the only part of the Saskeram Marshes which appears to be able to consistently sustain fish overwinter, or conversely, suffers the least degree of winterkill, is the upper Birch River immediately downstream of Cumberland Dam. A summary of winter oxygen concentrations in this area and the prevailing weather conditions in each winter (Table 38) reveals no clue as to reasons for winter fishkills in this area. The years in which the greatest fishkills were observed (1980/81 through 1982/83) generally exhibited favourable winter weather conditions and high oxygen levels. However, if we consider diversions of water from the Cut Beaver Reservoir into the Saskeram Marshes during previous summers, the reason for the observed fishkills and their magnitude becomes apparent. Since fish populations in the Cut Beaver Reservoir have been maintained througout the winter by flows from the Old Channel, Saskatchewan River, via Dragline Channel, water from the area will carry with it the various fish species found upstream of Bracken Dam (Appendix XXXII). In the case of pike, it is known that only small numbers (<50) of adults moved into the Saskeram Marshes via Bracken Dam during the 1981 spring spawning run (Leroux 1982). This small parental stock could not have produced the numbers of juvenile pike that were observed in the 1981/82 winterkill. Since Bracken Dam was closed by the beginning of September, the fish which had been washed down from the Cumberland Marshes, as well as perhaps the progeny of fish which had entered the Saskeram Marshes at Bracken Dam, could not escape before freeze-up and died of winterkill.

A larger volume of water (26,500 dam^3) was diverted from Cut Beaver Reservoir to the Saskeram Marshes in 1982 than in 1981. As there is usually a direct relationship between the numbers of fish transported and the amount and duration of diverted flows, it might be assumed the quantity of fish flushed into the Saskeram Marshes in 1982 exceeded the amount transferred in 1981. A substantial number of fish also entered the Saskeram Marshes at Bracken Dam during the spring

Table 38. A summary of dissolved oxygen DO_2 levels in the Birch River immediately downstream of Cumberland Dam during the winters 1980/81 to 1984/85 as compared to prevailing winter weather conditions; these are expressed as a deviation from average conditions for The Pas area. Volumes (dam^3) of water diverted from the Saskatchewan River (Old Channel) and/or Cut Beaver Reservoir in the openwater period previous to each winter are also given.

	DO_2 reading ($mg \cdot \ell^{-1}$)			Winter Conditions		Previous diversions from Cut Beaver Res.
Winter	Jan.	Feb.	Mar.	Temp.[1]	Snowfall[2]	
1980/81	7.5*			Above	Below	45,600
1981/82		6.4* 0.6		Below	Below	18,500
1982/83	4.5* 4.5		8.3*	Above	Above	26,500
1983/84	5.7* 3.5-7.1	0-5.2	4.8*	Above	Above	0
1984/85		5.6		N.D.	N.D.	15,100

* From Crosley (1985).

[1] Deviation of average monthly winter temperature from long term monthly mean.

[2] Cumulative winter snowfall less than or greater than average winter snowfall (~120 cm).

N.D. = No Data.

spawning run in 1982. Leroux (1982) estimated that some 20,000 pike and 1200 white suckers moved upstream through Bracken Dam during the 1982 spawning run. In the case of pike, much fewer adults and a very small number of underyearling pike were observed leaving the marsh right up until freeze-up. It has been postulated that the small return of young pike reflected a near total year class failure due to a continuing drop in water levels during the spawning-incubation period (Fig. 53). If pike reproduction had been even reasonably successful, large numbers of young pike should have been observed at Bracken Dam. Flows through the fishway and one of the spillway bays at Bracken Dam were screened until mid-December. Winterkilled juvenile pike seen in the Saskeram Marshes during December likely originated from the Cumberland Marshes. A large proportion of the adult pike which entered the Saskeram Marshes during the spring appeared to remain in the marshes for the winter. Many of these adult pike, as well as some white suckers, must have survived the winter; only this can explain the large number of untagged pike and suckers we encountered in the Saskeram Marshes during the first year of this study. Since no observations on winter fishkills were made after December, it is not known where these fish may have overwintered.

In 1983, there was no diversion of Cut Beaver water into the Saskeram Marshes; only internal water from MacGregor Lake at the east end of the Cumberland Marshes was released to the Saskeram. Since this area of the Cumberland Marshes is also prone to annual winterkill, it is doubtful that water from the area could have contributed any large fish to the Saskeram Marshes in 1983. Although dead juveniles were found throughout the Saskeram Marshes in 1983/84, there were no indications that a major fishkill had occurred. Outflows at Bracken Dam were maintained well after the marshes had frozen over. Since approximately 30,000 juvenile pike were tallied moving out of the Saskeram Marshes, it is surmised that only a small proportion of the pike produced in the marshes that year remained.

During 1984, further diversions of water were made from Cut Beaver Reservoir to the Saskeram Marshes. Between July 26 and August 10, some 1200 dam^3 of water from Cut Beaver Reservoir were routed into the Bewley and Beaton lakes area at the same time that water was being routed from these lakes through Cumberland Dam into the Saskeram Marshes. Even though the fish exclusion net was in place at the outlet of Cut Beaver Lake at this time, the diversion still resulted in the downstream transfer of fish. Good samples of young-of-the-year pike, as well as a few yearlings, were caught in Bewley Lake in the Cumberland Marshes in August and October (see Fig. 36). Between August 13 and October 10, some 14,000 dam^3 were diverted into the Saskeram Marshes via the upper Birch River. As varified by the unusual size ranges of pike and white suckers caught at Bracken Dam during the latter part of this diversion, the net at the outlet of Cut Beaver Lake was not very effective in precluding the downstream transfer of fish of virtually all size ranges. Not all of the fish flushed into the Saskeram Marshes were able to escape to the Saskatchewan River before freeze-up as indicated by the several thousand winterkilled pike observed downstream of Cumberland Dam on February 20, 1985.

The foregoing discussion underlines the biological importance of the Saskeram Marshes to the fish community, and particularly the pike populations of the Saskatchewan River. If fish access to the Saskeram Marshes was excluded, the lost fish production would have to be replaced by hatchery means. The cost of replacing the lost pike production alone would be substantial. According to the American Fisheries Society (1975), the cost of producing a 250 mm pike under hatchery conditions is approximately $2.85. Given inflationary trends since the early 1970's, the price today is perhaps closer to $3.50. Assuming the Saskeram Marshes contribute 40,000 pike of that size annually, the fisheries value of the Saskeram is in the order of $150,000. As noted earlier, the annual production of 40,000 young-of-the-year pike from the Saskeram Marshes could be much higher and fisheries values may well be in excess of $0.5 million in some years. These values may be further enhanced if provisions are made to increase the fall escapement of fish from the marshes or oxygen conditions below Cumberland Dam are improved to permit greater overwinter survival in the upper Birch River.

SUMMARY AND CONCLUSIONS

The Saskeram Marshes form a part of the Saskatchewan River Delta. Since 1940, the Saskeram Marshes have been managed by Ducks Unlimited for the production of waterfowl and muskrats. This management has historically consisted of maintaining water levels. In recent years, Ducks Unlimited has introduced drawdown cycles on portions of Saskeram and the upstream Cumberland marshes to enhance habitat conditions for waterfowl and muskrats. During the 1980/81 winter season a substantial fishkill was observed in the Saskeram Marshes, which caused concerns over the impact of water management regimes on fish populations in the area. Following some preliminary monitoring in 1981 and 1982, a intensive two-year investigation was undertaken to address these concerns. The specific purpose of this study was to establish the advantages or disadvantages of allowing fish access to the Saskeram Marshes via Bracken Dam.

Large fish species, which have been observed moving into the Saskeram Marshes to spawn, include northern pike, white suckers, walleyes and carp. Based on the observations made in 1983 and 1984, the fish ladder at Bracken Dam appears to be adequate to allow upstream passage of the above species under virtually all flow conditions. The average head which fish may encounter at Bracken Dam during the spring spawning period (April to June) is approximately 1.0 m. Spawning runs through Bracken Dam consist mainly of pike and white suckers. Approximately 70 per cent of the total pike runs and 90 per cent of the white suckers runs through Bracken Dam were completed within two weeks of their inception. In 1983, the numbers caught during this period of time were 213 pike and 350 white suckers, while 663 pike and 456 suckers were intercepted in the 1984 early run. Movements of pike and white suckers through Bracken Dam in 1984 were curtailed by a severe snowstorm and inclement weather one week after the run began. One hundred and eight spawning walleyes and 68 carp spawners were caught at Bracken Dam in 1983; less than 30 of each species were caught in 1984. The spawning run of walleyes appeared to coincide with those of pike and white suckers, while the carp run began several weeks later. The spawning runs of pike and white suckers were simultaneous and began shortly after breakup when water temperatures had risen to 5°C. No pronounced diel behaviour was apparent in the spring movements of fishes through Bracken Dam, although there was some suggestion that upstream movements may have been greater during daylight.

The population characteristics of pike spawning runs into the Saskeram Marshes were not unusual from those reported in other studies. The sex ratio in pike intercepted at Bracken Dam varied from 2 to 3 males per female. Most of the adult pike in both years fell within the 40 to 50 cm size range and varied between 2 and 5 years of age. The 1984 pike spawning run differed from the 1983 run in that it contained a relatively higher proportion of yearling fish. Pike in 1984 matured almost a full year earlier than pike in 1983. The range in length of spawning run white suckers tended to be similar to that observed for pike (i.e. 40 - 50 cm). but the sucker runs were represented by older fish (mostly 6 to 10 years of age). Spawning run walleyes in 1983 were represented by fish which ranged from 35 to 50 cm in fork length and which were mostly 6 to 8 years old. Spawning run carp caught at Bracken Dam in June, 1983. were large (60 - 70 cm), old (9 - 20 years) fish.

Adult pike entering the Saskeram Marshes appeared to scatter quickly throughout the marsh. No evidence was found to indicate that they remained to spawn in the Birch River immediately upstream of Bracken Dam or in the deep channels around the outlet of Saskeram Lake. Although the distribution of pike in the Saskeram Marshes could not be documented, it is speculated, based on the known habitat preferences of pike and the general habitat conditions in the Saskeram Lake area that they moved into the shallow, grassy areas around the eastern and southern fringes of Saskeram Lake to spawn. The large members of young-of-the-year pike caught leaving the marshes in 1983 and 1984 indicate the suitability of the Saskeram Marshes as spawning habitat for pike. The observation of a much smaller number of young-of-the-year white suckers and only an occasional small walleye and carp indicates the marshes are less suited to the reproduction of those species.

A mark and recapture experiment in 1983 was conducted from the onset of the spawning run (May 15) to estimate the population sizes of adult pike and white sucker in the Birch River above Bracken Dam. The estimated size of the pike population was 3000 to 3100 individuals, while the population size of white suckers was determined to be about 1100. These estimates were considerably greater than the numbers of adult pike and white suckers recorded going into the Saskeram Marshes. Only 318 pike and 388 white suckers were noted moving upstream at Bracken Dam in 1983. The additional 2800 pike and the 700 white suckers were believed to be fish which had overwintered in the marshes.

Trap netting and gillnetting in the lower Birch River and the recapture of tagged fish at Bracken Dam during 1983 revealed that many adult pike begin leaving the Saskeram Marshes within 30 to 40 days after spawning or from late June to early July. The numbers leaving the marshes drop off during mid-summer, but peak again between the beginning of September and freeze-up. Curtailment of outward movements was coincident with water temperature approaching 4°C. Not all adult pike appear to leave the marshes for the winter. In 1984, only 16 per cent of the 721 adult pike which moved into the marsh were recaptured coming out. Based on the 1983 results, all of the adult suckers which entered the Saskeram Marshes in the spring appeared to have left the marshes by the end of July. Recaptures of only 6 per cent of the 380 adult suckers marked in 1984 suggested most of the fish may have remained in the marshes. Only small proportions (10% or less) of the walleyes and carp passing into the marshes in 1983 were recaptured leaving. Movements of fish out of the Saskeram Marshes in 1983 were difficult to discern because of large volume releases at Bracken Dam May 15 to August 13 during that summer. A total of 536 adult pike and 217 adult white suckers, both-tagged and untagged, were enumerated leaving the Saskeram Marshes in 1983. In 1984, the numbers were 1850 and 769, respectively, and consisted principally of untagged fish. Most of these fish are believed to have originated from the Cumberland Marshes and specifically the Cut Beaver Lake area during spilling operations at Cumberland Dam between mid-August and early October.

During this study, almost 80,000 young-of-the-year pike were enumerated leaving the the Saskeram Marshes. Most of these fish (44,400) were encountered in 1984, although escapement in 1983 may have been higher than the 35,000 tallied. The pattern of young-of-the-year pike movements out of the marshes was the same in each year. Except for minor peaks in early July and early August, peak outward movements occurred during the first two weeks of November. The fall exodus of young pike began about October 1 and continued until the marshes became anoxic. Anoxic conditions were encountered approximately one month after freeze-up on the marshes. Outward movements of juvenile white suckers were not as pronounced as those of underyearling pike. A total of only 627 juvenile suckers were caught outbound at Bracken Dam in 1983 and 1984. Although the outmigration of juvenile white suckers was more erratic, there appeared to be marked peaks in activity throughout July and around the beginning of November.

Recoveries of tagged adult pike downstream of Bracken Dam revealed that most did not move more than 10 km and remained within the vicinity of the Carrot River - Saskatchewan River confluence. Pike which had moved farther tended to travel downstream in the Saskatchewan River, in a few cases as distant as Cedar Lake. A few pike swam upstream as far as Cumberland House and the Squaw Rapids Dam tailrace in Saskatchewan. Occasional recoveries were also made in the Reader-Root Marshes northwest of The Pas and upstream in the Carrot River. A relatively small number of the tagged white suckers was recovered and most were reported caught in the vicinity of The Pas. Two tagged suckers were caught downstream in Cedar Lake and one upstream in Cumberland Lake, Saskatchewan. The distribution of adult walleye recoveries was similar to that noted for pike in the Saskatchewan River except that walleyes did not move as far upstream. Recaptures of 59 adult pike and 53 white suckers at Bracken Dam in spring spawning runs indicated a consistency on the part of these populations to return to the Saskeram Marshes to spawn. Some homing tendencies were also apparent in the walleye.

Pike populations monitored in the Saskeram Marshes throughout the openwater period consisted of mainly young fish, usually less than 6 years of age and were predominated by underyearlings. In 1983 and 1984, the adult pike ranged primarily around 40 to 50 cm in fork length. The modal length in length frequency distributions of young-of-the-year pike in 1984 was approximately 5 cm greater than observed in 1983. Age 0 female pike tended to be slightly larger than age 0 males, which indicates an early onset in the sexual dimorphism of growth.

The length frequency distributions of white suckers sampled in the Saskeram Marshes in 1983 and 1984 were similar, except for a disproportionately high number of smaller (30-35 cm) fish in 1984. In both years, the larger or adult suckers ranged primarily between 40 to 50 cm in length. The small suckers are believed to have been fish that were flushed from the Cumberland Marshes during the August to October diversion of water from Cut Beaver Lake. "Net scars" on number of these fish suggested that they may have forced their way through the exclusion net at the outlet of Cut Beaver Lake.

Walleyes sampled at Bracken Dam in 1983 were representative of the spawning population. Most of these fish ranged in age from 6 to 8 years. Female walleyes were similar in age to the males, but on average were 5 cm longer than the males.

Age specific lengths of pike in 1984 were 5 to 7 cm greater than those in 1983. Although pike at any given age in 1984 were larger than the 1983 pike, Walford plots suggested growth rates were similar in both years. Female pike tended to grow larger than males. From age 3 onward, the growth of adult Saskeram pike was similar to that reported for pike from the Netley-Libau Marshes and Lac La Ronge. Young-of-the-year pike were also larger in 1984 than in 1983, although growth rates in both years appeared the same. Length frequency distributions for underyearling pike in 1984 indicated the attenuation of growth by September. Age specific lengths of Saskeram pike from age 0 to 2 were greater than reported elsewhere.

Plots of age specific lengths of adult walleyes, as well as of carp, were very similar between 1983 and 1984; this contrasts with the divergence in age specific lengths for pike in the two years. Both adult walleyes and carp, unlike the adult pike, do not appear to stay in the marsh for any length of time.

The average conditon factor for Saskeram pike was better than that reported for pike populations in other Precambrian lakes in Manitoba. Sexual maturation of Saskeram pike in 1983 and 1984 occurred before the age of 2 years. Annual mortality rates of pike and walleyes were as high as 70 to 80 per cent, while those for white suckers and carp were 40 to 50 per cent.

Adult pike in the Saskeram Marshes fed principally on invertebrate organisms, particularly leeches and amphipods, during the early part of the openwater season. By June, fish such as brook sticklebacks made up 61 per cent of the food organisms ingested by adult pike. Young waterfowl did not constitute a significant item in the diet of adult pike. Only two birds, a coot and a grebe, were encountered in the two years.

Feeding habits of young-of-the-year pike were examined from July until freeze-up in each year. The proportion of young pike inspected in 1983 which contained food (54%) was greater than that in 1984 (43%). Invertebrate organisms were more commonly observed in young pike in 1983 than in 1984; fish were more important in 1984. In 1983, brook sticklebacks were the most frequently consumed species, whereas in 1984 both sticklebacks and fathead minnows were of equal importance in the diet of young pike.

Based on the documented habitat requirements of northern pike, the Saskeram Marshes provide ideal spawning and nursery habitats for pike. The sedge and grassy areas along the fringes of the Saskeram Lake area between the 260 m and 259.5 m contours are believed to be the preferred spawning habitat for young pike. The deeper central area of Saskeram Lake provides excellent rearing habitat for the young pike. A significant factor which appears to limit pike reproduction is spring water levels. Minor changes in water levels may affect significant portions of the Saskeram Lake fringes where pike are believed to spawn. If such changes occur during the spawning, incubation and prolarval stages of pike, they could dewater the eggs or immobile larvae and result in a significant decline in reproductive success. Such circumstances are believed to have occurred in 1982, when water levels in the Saskeram Lake area began dropping at the end of April and continued to drop steadily throughout the critical incubation and prolarval stages of pike. Increasing water levels on the other hand, would have greatly enhanced reproductive success.

Another factor which limits the suitability of the Saskeram Marshes as pike habitat is summerkill. Summerkill conditions do not appear to be a frequent event in the marshes. The summerkill of pike witnessed in 1983 appeared to be generated by a mid-summer decline in oxygen concentration coupled with a very sudden and marked increase in water temperatures. High temperatures alone were not the sole contributing factor to the summerkill since water temperatures in 1984 were higher than in 1983.

A common event on the Saskeram Marshes is winterkill. In the last five winter seasons, winterkills of fish which may be termed as severe have been observed in three years (1980/1981 to 1982/83). Evidence, such as the large numbers of unmarked pike and suckers encountered in the Saskeram Marshes during the early summer in 1983, indicates some fish do survive in the marshes over the winter season. Overwinter survival of the larger fish appears most likely in the Birch River downstream of Cumberland Dam. The severity of winterkills in the Saskeram Marshes was associated with the duration/volume of releases to the marshes of water from the Cut Beaver Reservoir. For example, the most extensive fishkill was recorded in the 1980/81 winter season. This die-off followed a summer when exceptionally large volumes of water from Cut Beaver Reservoir were used to refill Saskeram Lake after drawdown. Fish populations in the Cut Beaver area of the Cumberland Marshes are maintained year-round by inflows from the Saskatchewan River during the winter months.

By permitting fish movements into and out of the Saskeram Marshes, a net gain of approximately 15,000 kg of pike was realized to

Saskatchewan River over two years. Most of this gain (83%) consisted of young-of-the-year pike. The Saskeram Marshes also added adult pike (1600kg) to populations in the Saskatchewan River.

Depending upon the wetted area of Saskeram Lake, the density of young-of-the-year pike in the area by autumn varied between 4 to 11 fish per hectare, while productivity ranged from 0.5 to 2.3 $kg.ha^{-1}$ Based on $P/\bar{B}$ ratios reported in the literature on pike, biomass values estimated for age 1 and older pike in the Saskeram Marshes may vary from 9.5 to 39.8 $kg.ha^{-1}$. The upper end of this range is slightly better than pike biomass levels reported for other Canadian and U.S. waters. The productive potential of the Saskeram Marshes for pike may be even greater, since the area was not fully utilized by the small spawning populations which entered the marshes in 1983 and 1984. Pike produced in the Saskeram Marshes benefit the pike populations localized in The Pas area of the Saskatchewan River. No positive benefits were apparent in the case of other fish species which moved through the Bracken Dam fish ladder into the Saskeram Marshes to spawn.

RECOMMENDATIONS

Based on the results of the 1983-1984 and previous investigations on the Saskeram Marshes fish populations, as well as information documented by other investigators, the following recommendations are made with the intention of mitigating fish losses and/or enhancing fish production in conjunction with the management of the area for waterfowl and furbearer production.

1. As it has been proven that a net benefit to local pike populations is derived by allowing fish into the Saskeram Marshes, it is recommended that fish access to the marshes at Bracken Dam not be excluded.
2. Timing of the spawning run of pike into the Saskeram Marshes at Bracken Dam varies from year to year, so no specific dates can be prescribed for opening the fish ladder. It is therefore recommended that the fish ladder be opened no later than breakup on the Carrot River, and that all stoplogs in the fish ladder exit be removed.
3. If spilling of significant quantities of water during the spring spawning runs is required, it is recommended that discharges be directed toward the south bank so as to attract fish into the fish ladder area.
4. In the event of high water levels and a reverse head at Bracken Dam, it is recommended that the fish ladder still be left open to allow fish access into the Saskeram Marshes during the spring spawning period.
5. The spawning runs of pike and white suckers at Bracken Dam last for about two weeks from the time fish are first noted moving through the fish ladder. In some cases, cold weather may reduce or even curtail

the spawning runs. In order to assure that most fish are able to move into the Saskeram Marshes, it is recommended that the Bracken Dam fish ladder should be left completely open until June 15. If a shortage of water is expected after June 15, the fish ladder may be partially closed.

6. Strong evidence was found to indicate that relatively minor changes in water levels on Saskeram Lake may cause excessive mortality of pike eggs or larvae. To avoid any negative impact on pike reproduction, it is strongly recommended that water levels on the Saskeram Lake area, as well as other areas of the Saskeram Marhses be kept stable or increased gradually, if possible, until at least June 15. Under no circumstances should any significant (i.e. >30 cm) drop in water levels be permitted during this period. As much as possible, spring water levels in the Saskeram Lake area should be held above the 259.7 m (852 ft) level.

7. Many of the adult fish which enter the Saskeram Marshes in the spawning runs return to the Saskatchewan River within 30 to 40 days after spawning. It is therefore recommended that a minimum outflow (∿ 5 cfs) at Bracken Dam be maintained to permit the escapement of these fish. This outflow should also be continued during late July and early August (i.e. July 20 - August 10) to allow the escapement of both adult and juvenile pike should potential summerkill conditions develop. In the event that water levels below Bracken Dam during those periods are so low that fish may be injured in the fall, the outflow should be through the fish ladder rather than through stoplog bays.

8. Results of this study indicate that the movement of young-of-the-year pike out of the Saskeram Marshes in the autumn is a predictable event. Adult pike movements out of the marsh also increase, but they are not as pronounced. These movements peak in late October - early November and are discontinued when Saskeram Lake and the lower Birch River reach an anoxic state. Based on these findings, it is recommended that the Bracken Dam fish ladder be kept open from October 1 until December 15, or after freeze-up on Saskeram Lake. Flows out of the marshes should be maintained at 10 cfs. The fish ladder should not be closed until chemical analysis indicates there is no further oxygen in the Birch River above Bracken Dam. The onset of anoxic conditions may vary from year to year depending on ice conditions and the depth of snow cover.

9. Based on several years of observations, it is evident that winterkills on the Saskeram Marshes are integrally related to water releases from the Cut Beaver Lake area directly or indirectly to the Saskeram Marshes during the openwater seasons. Diversions of water which originate from the Cut Beaver Lake area will transport fish into the Saskeram Marshes. The quantity of fish transferred appears to be directly related to the volume and duration of flows. The net barrier at the outlet of Cut Beaver Lake seems to be largely ineffective in preventing such fish transfers. It is therefore recommended that at any time water from the Cut Beaver area is diverted directly to the Cumberland Dam or indirectly via other cells in the Cumberland Marshes, provisions be made to facilitate the escapement of fish from the Saskeram Marshes before freeze-up.

These provisions may be as follows:

a) Wherever possible, releases of water at Cumberland Dam late in the season, which may result in the stranding of fish, should be avoided.

b) With the installation of the Cook's Creek outlet for the northern portion of the Saskeram Marshes, flows from the upper Birch River (i.e. the area downstream of Cumberland Dam) may be maintained later in the fall season. This will permit the escapement of fish that concentrate below Cumberland Dam and will reduce winterkills in the area.

In the event that significant numbers of fish are still stranded in the marshes after freeze-up, consideration may be given to limited wintertime releases of water from Cumberland Dam to maintain suitable oxygen concentrations. Because of the anoxic conditions of water upstream of Cumberland Dam, some type of aerating device (e.g. a baffled chute) may be necessary to oxygenate the water. In years when large volumes of water from Cut Beaver Lake are required (e.g. following the drawdown phase of a given cell in the marshes or during drought conditions) and when it appears that many fish may become exposed to winterkill in the marshes, winter fish rescue operations, such as described by Hanson (1958) may be deemed necessary. Such rescue operations could be implemented upstream of Bracken Dam and the Cook's Creek control and extended for 4 to 6 weeks during the freeze-up period.

10. Water management of the Cumberland and Saskeram marshes is interrelated and may often have a direct bearing on fish

populations in the Saskatchewan River Delta both in Saskatchewan and Manitoba. It is therefore recommended that Fisheries Branch personnel from the two Provinces be fully apprised of any marsh management proposals that impinge on fish resources and be invited to the Saskeram Advisory Committee meeting to express their concerns.

11. The present study has illustrated that the Saskeram Marshes make a positive contribution to fisheries resources in the Saskatchewan River Delta. This study also indicates that this contribution could be substantially increased with some relatively minor adjustments to the current water management regime. The development of further water management capabilities on the Saskeram Marshes and on other marshes within the Saskatchewan River Delta are planned or in progress. Given the problems that have been encountered on the Saskeram Marshes, these developments in total could have major negative impacts on the fish resources of the entire Saskatchewan River Delta. It is therefore recommended that the assessment and monitoring of fish populations using the Saskeram, as well as other marshes, be continued. The assessment and monitoring of the Saskeram Marshes fish populations should include the following items:
    a) A pilot study to assess the feasibility of winter fish rescue operations.
    b) Springtime surveys of the shallow grassy fringes in the marshes to delineate the amount and extent of pike spawning areas. This information will allow for further refinement of the allowable variations in spring water levels.

c) Annual inspections to determine the extent of winterkills below Cumberland Dam and other control structures in the marshes.

d) Spring and fall trapping operations at the Cook's Creek control to determine the nature and extent of fish movements into and out of the marshes and the effectiveness of fish exclusion devices.

e) Development of a standardized format for reporting fishkills at various sites in the marshes.

12. Goldeyes were encountered in both the Saskeram and Cumberland marshes in very limited numbers. This species once flourished in the Saskatchewan River Delta and made a significant contribution to the development of Manitoba's commercial fishing industry. The goldeye stocks have declined because of man-made changes to the Delta. The goldeye may presently be considered as a heritage species. It is recommended that wherever possible future fisheries investigations in the Saskeram Marshes or other parts of the Delta give due consideration to the protection and enhancement of goldeye stocks.

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Appendix Ia. 1983 daily water temperatures (^{o}C) on upstream side of Bracken Dam recorded at noon at one metre depth with a Ryan thermograph (* surface temperature recorded with a rod thermometer).

Day	May	June	July	August	September	October	November	December
1		15.0	20.0	20.5		9.8	4.5	1.0
2		15.0	19.8	21.5	22.0 *	9.5	4.5	1.0
3		14.0	19.5	22.2	-	9.2	4.2	0.0
4		13.0	18.5	24.0	-	7.5	4.0	0.5
5		13.0	19.0	25.0	-	7.8	4.0	0.8
6	IN	13.5	18.5	25.0	-	7.8	4.0	0.8
7	3.2	15.0	19.0	24.5	-	7.8	4.0	0.8
8	3.2	15.5	19.5	23.8	-	7.8	3.8	1.0
9	3.5	17.0	19.5	23.0	-	7.5	3.0	1.0
10	3.8	18.0	20.0	22.0	-	7.5	2.5	1.2
11	2.0	19.5	20.0	22.0	-	7.5	2.5	1.2
12	2.0	19.5	19.8	22.5	-	7.5	2.2	-
13	2.5	18.0	20.5	22.0	16.0	7.0	0.5	1.0 *
14	2.5	17.0	21.0	22.0 *	14.5	6.8	0.5	OUT
15	3.0	17.5	22.0	21.5 *	14.0	6.5	0.8	
16	6.0	18.5	22.0	20.5 *	14.0	6.5	0.8	
17	8.5	19.0	21.5	21.0 *	13.2	6.0	0.8	
18	9.5	19.0	21.0	21.5 *	12.8	5.5	0.8	
19	10.0	19.5	20.8	19.5 *	11.2	5.0	0.8	
20	10.0	19.5	21.5	19.0 *	10.0	3.8	0.8	
21	10.5	20.0	22.5	18.5 *	9.5	4.0	0.8	
22	11.0	20.0	22.0	18.0 *	9.0	4.2	0.5	
23	11.0	20.0	21.5	18.5 *	9.0	4.5	0.5	
24	11.0	20.0	21.0	-	9.0	5.0	0.8	
25	11.0	20.0	22.0	-	9.2	5.0	1.0	
26	11.5	19.0	22.5	-	10.0	5.0	1.0	
27	12.0	19.0	22.5	-	10.0	5.0	1.0	
28	14.0	19.0	22.0	-	10.8	5.0	1.0	
29	14.0	19.5	21.5	-	10.5	5.0	1.0	
30	14.0	21.0	20.5	-	10.5	4.8	1.0	
31	14.0	θ	20.5	23.0 *	θ	4.5	θ	

Appendix Ib. 1984 daily water temperatures (^{o}C) on upstream side of Bracken Dam recorded at noon at one metre depth with a Ryan thermograph. (* surface temperature - rod thermometer).

Day	April	May	June	July	August	September	October
1		2.8	17.4	21.5	*25.0	15.1	6.0
2		5.5	16.5	21.1	24.5	15.0	6.0
3		7.0	14.8	20.8	24.5	14.9	6.0
4		9.5	13.9	20.0	24.5	14.8	6.0
5		10.2	15.0	19.5	24.0	14.5	6.0
6		10.0	15.8	19.0	24.3	14.5	6.0
7		8.5	16.3	18.8	24.0	14.5	6.1
8		7.5	16.3	18.7	24.5	14.0	6.2
9		8.5	15.8	19.4	24.0	13.0	6.8
10		10.0	15.2	19.4	23.4	12.4	7.9
11		8.5	15.5	21.8	23.0	12.0	8.8
12		8.8	16.3	21.0	22.9	11.6	9.4
13		10.4	16.0	21.0	22.9	11.4	9.9
14		11.0	16.4	21.0	22.9	11.3	10.0
15		12.3	17.8	20.9	23.0	11.0	10.0
16		13.0	18.5	20.2	22.0	11.0	9.8
17	IN	12.5	19.2	20.0	21.5	11.1	9.0
18	8.5	13.5	19.3	20.0	21.6	11.4	7.8
19	8.5	14.2	19.5	20.5	21.4	11.5	7.2
20	9.5	11.0	20.0	20.5	21.3	11.8	6.5
21	10.0	10.0	19.5	21.0	21.0	11.8	5.0
22	12.0	9.2	19.3	*22.5	20.4	10.5	5.0
23	12.5	9.5	19.0	*23.3	19.5	6.5	4.8
24	12.5	9.7	19.0	*23.0	19.0	6.2	4.4
25	12.2	9.7	19.0	*23.5	20.0	6.2	3.8
26	9.5	10.2	19.4	*23.0	20.0	6.2	3.5
27	6.0	12.0	19.8	*23.5	20.0	6.1	3.5
28	3.5	14.1	20.2	*23.0	20.0	6.0	3.3
29	2.0	15.0	20.8	*25.0	19.8	6.0	3.0
30	2.0	15.8	21.4	*25.3	18.5	6.0	3.0
31	0	16.9	0	*25.0	16.8	0	OUT

Appendix IIa. Daily temperatures and numbers of fish of each species recorded moving upstream through the Bracken Dam fish ladder in May 1983.

Date	Noon °C Water Temp.	Northern Pike	White Sucker	Walleye	Total
May 15	3	1			1
16	6	24	41	3	68
17	8.5	15	99	2	116
18	9.5	25	55	19	99
19	10	15	24	23	62
20	10	15	18	21	54
21	10.5	16	2	12	30
22	11	24	6	7	37
23	11	19	9	7	35
24	11	9	7	4	20
25	11	3		1	4
26	11.5	6	32	1	39
27	12	6	33	5	44
28	14	16	15	3	34
29	14	9	4		13
30	14	10	4		14
31	14		1		1
	Total	213	350	108	671

Appendix IIb. Daily water temperatures and numbers of fish of each species recorded moving upstream through the Bracken Dam fish ladder in June 1983.

Date		Water Temp. Noon °C	Northern Pike	White Sucker	Carp	Total
June	1	20	1			1
	2	19.8	1			1
	3	19.5		3		3
	4	18.5	1			1
	5	19	1	2		3
	6	18.5				
	7	19	6			6
	8	19.5				
	9	19.5				
	10	20				
	11	20	2			2
	12	19.8				
	13	20.5				
	14	21				
	15	22	1	1		2
	16	22	3			3
	17	21.5	4			4
	18	21	21		1	22
	19	20.8	5			5
	20	21.5	5			5
	21	22.5	2			2
	22	22				
	23	21.5	6	3		9
	24	21	12			12
	25	22	10			10
	26	22.5	2			2
	27	22.5	5			5
	28	22	2			2
	29	21.5		1		1
	30	20.5				
	31	20.5				
		Total	90	10	1	101

Appendix IIc. Daily water temperatures and numbers of fish of each species recorded moving upstream through the Bracken Dam fish ladder in July 1983.

Date	Water Temp. Noon °C	Northern Pike	White Sucker	Carp	Total
July 1	15	1		6	7
2	15		1		1
3	14		1		1
4	13	1	6		7
5	13	1			1
6	13.5	1	1	7	9
7	15		1	3	4
8	15.5			6	6
9	17	3	4	5	12
10	18			10	10
11	19.5	1	1	7	9
12	19.5		1	8	9
13	18		3	3	6
14	17			1	1
15	17.5		2	1	3
16	18.5			1	1
17	19		2	1	3
18	19	1		3	4
19	19.5		2	1	3
20	19.5			3	3
21	20			1	1
22	20		1		1
23	20				
24	20	2			2
25	20	3			3
26	19			1	1
27	19		1		1
28	19		1		1
29	19.5				
30	21	1			
	Total	15	28	68	111

Appendix IIIa. Daily water temperatures and numbers of fish of each species recorded moving upstream through the Bracken Dam fish ladder in April 1984.

Date	Surface °C Water Temp.	Northern Pike	White Sucker	Walleye	Total
April 19	8	66	107		173
20	10.5	108	77		185
21	12	126	171		297
22	12.5	69	45		114
23	13.0	100	27		127
24	13.5	110	19		129
25	11	46	10	1	57
27	8	38			38
28	4				
29	4				
30	5				
	Total	663	456	1	1120

Appendix IIIb. Daily water temperatures and numbers of fish of each species recorded moving upstream through the Bracken Dam fish ladder in May 1984.

Date	Water Temp Surface °C	Northern Pike	White Sucker	Walleye	Carp	Total
May 1	5					-
2	7					-
3	8.5	24	4	2		30
4	10.5	59	7	8		74
5	10	15		4		19
6	9.25	31	1	6		38
7	8					-
8	8.25					-
9	10			2		2
10	9	1				1
11	8					-
12	11	1		1		2
13	12					-
14	13.5		6	1		7
15	13.5					-
16	12.5	1	1	2		4
17	14.75					-
18	13					-
19	11.5		1			1
20	12	1	1			2
21	9.5					-
22	9.5					-
24	9					-
25	9.5	2	1			3
26	13					-
27	14	3	3			6
28	15.75	5	3		6	14
29	16.5		1		5	6
30	17	10	1		2	13
31	18	10	4		4	18
	Total	163	34	26	17	240

Appendix IIIc. Daily water temperatures and numbers of fish of each species recorded moving upstream through the Bracken Dam fish ladder in June 1984.

Date	Water Temp. Surface °C	Northern Pike	White Sucker	Carp	Total
June 1	17.5	6	4	2	12
2	15	1		1	2
3	14	4		1	5
4	14.5	5			5
5	16.5	2		1	3
6	18	6			6
7	17.5	6			6
8	16	2	4		6
9	15	4	4	1	9
10	15.25	3			3
11	16.5				-
12	17.5	1			1
13	18.5				-
14	19.5	1			1
15	20	1			1
16	21.5	2	1		3
17	20.75		2		2
18	20			1	1
19	19				-
20	20	1	1		2
21	19.5				-
22	19.3	1	4		5
23	20	6	2		8
24	20	4	4		8
25	20.9	1	1		2
26	21	4	5	1	10
27	23	5			5
28	23.5	4	1		5
29	23.5	5			5
30	22.5	1			1
	Total	76	33	8	117

Appendix IVa. Summary of numbers of fish tagged in 1983 (2312 tags issued).

	Bracken	Pyott's Crossing		Saskeram Lake Outlet				
	Dam	Upstream	Downstream	Upstream	Downstream	Birch River	Totals	
Northern Pike								
May	203	18				2 (G)*	223	
June	15	85	340	112	149	35 (G)* 4 (B)	740	
July	78	25	324	34	56	23 (G)	540	
August		10	70	3	57	1 (G)	141	
	296	138	734	149	262	61 (G) 4 (B)		1644
White Sucker								
May	214	14					228	
June	29	2	79	2	15	1 (G) 1(B)	129	
July	10	4	51	1	60	1 (G)	127	
August					1		1	
	253	20	130	3	76	1 (B) 2 (G)		485
Walleye								
May	107							
	107						107	107
Carp								
June	63		1		3		67	
July	1		1		7		9	
	64		2		10		76	
							2312	

*G = Gillnet B = Beamish net

Appendix IVb. Summary of numbers of fish tagged in 1984 (3349 tags issued).

	Bracken Fishway		Bracken Dam (Downstream)		Beamish Trap	Fyke Net	Gillnet	
	Upstream	Downstream	South Spillway	North Spillway	Pyotts Cross	Pyotts Cross	(Cumberland Dam)	Totals
Northern Pike								
April	475							475
May	157							157
June	75						14	89
July	14	53	18	1	3			89
August		13						13
September		306	270	82		1		659
October		311	343	83				737
	721	683	632	166	3	1	14	2219
White Sucker								
April	312							312
May	32							32
June	33							33
July	3	5	26	47				81
August		40	2	5				47
September		276	14	13		1		304
October		261	1	4				266
	380	582	43	69		1		1075
Walleye								
April	1							1
May	26							26
	27							27
Carp								
May	16							16
June	6							6
	22							22
Burbot								
October		5						5
		5						5
Northern Redhorse Sucker								
October		1						1
		1						1

Appendix Va. Bracken Dam spillway trap catches, June - November 1983.

Time	N. Pike		W. Sucker		Walleye	Carp	Total	
Period	Adult	Juvenile	Adult	Juvenile	Adult	Adult	Adult	Juvenile
June								
1-5			1				1	
6-10	9		8	1			17	1
11-15	15		106	1	6		127	1
16-20	12		39	1	3	4	58	1
21-25	58		51		1	4	114	
26-30	96		5		1	14	116	
July								
1-5						4	4	
6-10		167		9				176
11-15		934		25				959
16-20		354		14				368
21-25		24		15			1	39
26-31		33		7				40
Aug.								
1-5	1	438		3			1	441
6-10	1	93					1	93
11-15		6						6
16-20	13	1					13	1
21-24	2			1			2	1
Sept.								
12-15	4	32					4	32
16-20	18	29		1			18	30
27-30	18	11					18	11
Oct.								
1-4	17	569					17	569
12-15	18	140					18	140
16-19	5	113					5	113
25-31	3	1253		10			3	1263
Nov.								
7-10	1	1967		12			1	1979
11-15		302		2				304
16-20	2	343		1			2	344
21-24	2	653		6			2	659
	296	7462	210	109	11	26	543 +	7571 =
								8114

Appendix Vb. Bracken Dam fish ladder D/S trap catches, September 27 - December 15, 1983.

Time	N. Pike		W. Sucker		Total	
Period	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Sept.						
27-30	11	1			11	1
Oct.						
1-4	19	134			19	134
13-15	45	376	1		46	376
16-19	72	3228	1	4	73	3232
25-29	50	3729	3	110	53	3839
30-31	5	1197		55	5	1252
Nov.						
8-12	1	4235		39	1	4274
13-17	9	4634		13	9	4647
18-22	20	5773	2	16	22	5789
23-25	6	1483		3	6	1486
29-30		349				349
Dec.						
1-5	2	1714			2	1714
6-10		436				436
11-15		2				2
	240	27291	7	240	247	27531

Appendix VIa. Bracken Dam north spillway trap catches June 25 - November 19, 1984. (Mortality in brackets).

Time	Northern Pike		White Sucker				Total	
Period	Adult	Juvenile	Adult	Juvenile	Goldeye	Burbot	Adult	Juvenile
June								
25 - 30	1	12 (2)		56			1	68
July								
1 - 5		11		1				12
6 - 10	2	7		8			2	15
11 - 15	6 (5)	66 (17)		11 (6)			6 (5)	77 (23)
16 - 20	2	3 (3)		22			2	25 (3)
21 - 25		1 (1)		17				18 (1)
26 - 30		4 (4)		4				8 (4)
31 - Aug. 4		2 (2)						2 (2)
5 - 9		37 (31)	3	5			3	42 (31)
10 - 14		6		6				12
15 - 19		4 (1)						4 (1)
20 - 24		4 (3)		1 (1)				5 (4)
25 - 29								
30 - Sept. 3		5 (5)						5 (5)
4 - 8				1 (1)				1 (1)
9 - 13	9 (1)	1			1 (1)		10 (2)	1
14 - 18	41 (1)	15 (15)	13 (1)				54 (2)	16 (16)
19 - 23	4 (1)	1 (1)					4 (1)	1 (1)
24 - 28	32 (10)	97 (36)	1	1 (1)			33 (10)	98 (37)
29 - Oct. 3	51	79 (3)					51	79 (3)
4 - 8	29 (1)	57 (6)	1			1	31 (1)	57 (6)
9 - 13	4	11	2				6	11
14 - 18	14	120 (9)	1			1	16	120 (9)
19 - 23	3	273					3	273
24 - 28		83						83
29 - Nov. 2		787						787
3 - 7	2	6224 (134)		2 (2)			2	6226 (136)
8 - 12		1371 (186)		5 (5)				1376 (191)
13 - 17		5722 (913)						5722 (913)
18 - 19		2						2
Totals	202 (19)	15002 (1372)	21 (1)	141 (17)	1 (1)	2	224 (21)	15146 (1389)
Mortality rates	10%	9%	5%	12%			9%	9%

Appendix VIb. Bracken Dam south spillway trap catches, July 8 - November 10, 1984.

Time Period	Northern Pike Adult	Northern Pike Juvenile	White Sucker Adult	White Sucker Juvenile	Goldeye	Northern Redhorse Sucker	Burbot	Total Adult	Total Juvenile
July									
8 - 10	41	4	1	3				42	7
11 - 15	21	48 (12)	1	24				22	72 (12)
16 - 20	5 (1)	4 (3)		2				5 (1)	6 (3)
21 - 25				18					18
26 - 30	Trap removed for repairs July 27								
31 - Aug. 4	- Reinstalled Aug. 4								
5 - 9	3 (2)	50 (35)		3 (1)				3 (2)	53 (36)
10 - 14		14 (11)							14 (11)
15 - 19	1	13 (9)		1 (1)				1	14 (10)
20 - 24		11 (11)							11 (11)
25 - 29	1	3 (3)	1					2	3 (3)
30 - Sept. 3	3	14 (14)						3	14 (14)
4 - 8	2	4 (4)						2	4 (4)
9 - 13	62 (9)		4 (3)		1 (1)			67 (13)	
14 - 18	81 (23)	15 (14)	11 (3)	1 (1)	3 (3)			95 (29)	16 (15)
19 - 23	12 (1)	1 (1)	1					13 (1)	1 (1)
24 - 28	74 (17)	203 (117)	8 (3)			1		83 (20)	203 (117)
29 - Oct. 3	187	245 (54)	1					188	245 (54)
4 - 8	121	205 (25)					1	122	205 (25)
9 - 13	54	75 (1)						54	75 (1)
14 - 18	49	239 (89)	1		1			51	239 (89)
19 - 23	32	468 (36)						32	468 (36)
24 - 28		221 (86)							221 (86)
29 - Nov. 2		1091 (271)		1					1092 (271)
3 - 7	2	3980 (1352)		20 (16)				2	4000 (1368)
8 - 12	2	2737 (1366)		9 (9)				2	2746 (1375)
13 - 17	2	5016 (3477)	1					3	5016 (3477)
18 - 20		7 (2)							7 (2)
Totals	755 (53)	14668 (6993)	30 (9)	82 (28)	5 (4)	1	1	792 (66)	14750 (7021)
Mortality rate	7%	48%	30%	34%				8%	48%

Appendix VIc. Bracken Dam fish ladder D/S trap catches, July 10 - November 22, 1984. (Mortality in brackets).

Time	Northern Pike		White Sucker		Goldeye		Northern Redhorse			Longnose Sucker	Total	
Period	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Sucker	Burbot	Walleye	Juvenile	Adult	Juvenile
July												
11 - 15	74 (28)	18	2	8							76 (28)	26
16 - 20	25	2 (2)	1	1							26	3 (2)
21 - 25	16										16	
26 - 30	5										5	
31 - Aug. 4	20	3 (3)		1							20	4 (3)
5 - 9	3	16 (2)	3	42							6	58 (2)
10 - 14	3										3	
15 - 19	3			1							3	1
20 - 24	2	7 (7)									2	7 (7)
25 - 29	2	2									2	2
30 - Sept. 3	4	14 (12)	104 (69)								108 (69)	14 (12)
4 - 8	1	2 (2)									1	2 (2)
9 - 13	88 (3)	4 (4)	29 (1)								117 (4)	4 (4)
14 - 18	131 (2)	34 (34)	189 (2)		1 (1)	1 (1)			1 (1)	1 (1)	322 (6)	36 (36)
19 - 23	38 (5)	3 (3)	13								51 (5)	3 (3)
24 - 28	81 (16)	307 (255)	44 (4)		1 (1)						126 (21)	307 (255)
29 - Oct. 3	47 (30)	143 (56)	29 (1)		2 (2)		1				79 (33)	143 (56)
4 - 8	119	239 (5)	34		1						154	239 (5)
9 - 13	118	66	148		1			1			268	66
14 - 18	29	381 (68)	56		2 (1)			1	1 (1)		89 (2)	381 (68)
19 - 23	32 (2)	1966 (541)	6	1							38 (2)	1967 (541)
24 - 28	25 (3)	1737 (694)	1								26 (3)	1737 (694)
29 - Nov. 2	16 (2)	5857 (1403)	8	1 (1)							24 (2)	5858 (1404)
3 - 7	1	618 (266)	51								52	618 (266)
8 - 12	10 (2)	1941 (934)									10 (2)	1941 (934)
13 - 17	2	1313 (457)									2	1313 (457)
18 - 22		19 (19)										19 (19)
Totals	895 (93)	14692 (4767)	718 (77)	55 (1)	8 (5)	1 (1)	1	2	2 (2)	1 (1)	1626 (177)	14749 (4770)
% Mortality	10%	32%	10%	2%	63%						11%	32%

Appendix VIIa. Fish outmigration at Bracken Dam recorded as a mean daily catch per unit effort, June 1 - December 15, 1983.

Time Period	Mean Water Temp. °C	Northern pike		White sucker		Walleye	Carp
		Adult	Juvenile	Adult	Juvenile	Adult	Adult
June 1 - 5	13.7			0.2			
6 - 10	15.8	1.8		1.6	0.2		
11 - 15	18.3	3.0		21.2	0.2	1.2	
16 - 20	19.1	2.4		7.8	0.2	0.6	0.8
21 - 25	20.0	11.6		10.2		0.2	0.8
26 - 30	18.5	19.2		1.0		0.2	2.8
July 1 - 5	19.3						0.8
6 - 10	19.3		33.4		1.8		
11 - 15	20.6		186.8		5.0		
16 - 20	21.3		70.8		2.8		
21 - 25	21.8	0.2	4.8		3.2		
26 - 31	21.5		5.5		1.2		
Aug. 1 - 5	22.6	0.2	87.6		0.6		
6 - 10	23.6	0.2	18.6				
11 - 15	22.0		1.2				
16 - 20	20.3	2.6	0.2				
21 - 24	18.3	0.5			0.3		
Sept. 12 - 15	14.8	1.0	8.0				
16 - 20	12.2	3.6	5.8		0.2		
27 - 30	10.3	7.2	3.0				
Oct. 1 - 4	8.7	9.0	175.8				
12 - 15	7.0	15.8	129.0	0.3			
16 - 19	5.7	19.3	835.3	0.3	1.0		
25 - 31	4.8	8.3	882.7	0.4	25.0		
Nov. 7 - 10	3.3	0.4	1040.0		9.6		
11 - 15	1.3	1.0	870.4		2.6		
16 - 20	0.8	3.6	1224.6	0.4	3.6		
21 - 25	0.7	3.2	743.0		2.6		
26 - 30	1.0		69.8				
Dec. 1 - 5	0.7	0.4	342.8				
6 - 10	0.9		87.2				
11 - 15	0		0.4				

Appendix VIIb. Fish outmigration at Bracken Dam recorded as a mean daily catch per unit effort, June 25 - November 20, 1984.

Time Period	Mean Water Temp. °C	Northern Pike		White Sucker		* Other (23 Fish)
		Adult	Juvenile	Adult	Juvenile	
June 25 - 30	20.1	0.2	2.4		11.2	
July 1 - 5	20.6		2.2		0.2	
6 - 10	19.1	8.6	2.2	0.2	2.2	
11 - 15	21.1	20.2	26.4	0.6	8.6	
16 - 20	20.2	6.4	1.8	0.2	5.0	
21 - 25	22.7	3.2	0.2		7.0	
26 - 31	24.1	1.8	0.7		0.7	
Aug. 1 - 5	24.5	3.2	1.8		0.4	
6 - 10	24.1	1.2	19.8	1.2	10.6	
11 - 15	22.9	0.2	4.8		0.6	
16 - 20	21.6	0.8	5.6		0.2	
21 - 25	20.0	0.4	2.0		0.2	
26 - 31	19.2	0.5	1.7	17.5		
Sept. 1 - 5	14.9	2.0	6.8		0.2	
6 - 10	13.7	10.0		0.8		0.2
11 - 15	11.5	45.2	6.0	22.6	0.2	0.8
16 - 20	11.4	38.0	8.0	28.6	0.2	0.6
21 - 25	8.2	10.2	22.6	1.8		0.4
26 - 30	6.1	51.6	132.6	11.2	0.2	
Oct. 1 - 5	6.0	60.2	88.2	6.8		0.6
6 - 10	6.6	42.8	79.4	23.8		0.8
11 - 15	9.6	25.2	33.2	11.8		0.8
16 - 20	8.1	20.2	477.6	10.6		0.4
21 - 25	4.6	8.6	286.2	0.4	0.2	
26 - 31	3.3	4.3	924.5	1.2	0.3	
Nov. 1 - 5	Birch River	1.4	2444.4	10.6	1.0	
6 - 10	u/s and	1.8	1091.4		5.8	
11 - 15	Carrot River	1.0	2507.2		0.4	
16 - 20	frozen over	0.4	507.8	0.2		
	October 31					

* Goldeye (13)
Longnose Sucker (1)
Redhorse Sucker (2)
Walleye (2)
Burbot (5)

Appendix VIIIa. Numbers of adult pike tagged, recaptured, released and removed from the Saskeram Marsh during May 15 - November 26, 1983.

Date	Number "Entering" Birch River System				Total Number Entering	Number Removed From System			
		Tagged				Tagged		Untagged	
	Nets	Bracken Dam	Pyott's Crossing	Saskeram		River/Marsh	Bracken Dam	River/Marsh	Bracken Dam
May									
15	2				2				
16		18 (6) *	1		25				
17		15			15				
18		22 (3)			25				
19		15	5		20				
20		15	1		16	2 (2) +		52	
21		16	2		18	2 (2)		24	
22		24			24			19	
23		19			19	(1)		8	
24		9	3		12	(4)		9	
25		3			3	3		44	
26		5 (1)			6	1		3	
27		6			6			5	
28		16	2		18			4	
29		9	1		10	1		22	
30		10	3		13	1 (1)		29	
31			2		2			16	
June									
1		1			1	2		19	
2			1		1	1		23	
3			3		3	2		19	
4		1			1			22	
5		1	6		7			9	
6		1			1			13	
7			12		12	1		23	1
8			19		19	3 (3)		21	5
9		3	4		7	2 (2)		20	
10			3		3	2 (3)	1	22	2
11		1	13		14	3 (6)		15	2
12			15		15	2 (9)	1	21	3

* Pike which escaped untagged.

+ Tagged pike re-released into system.

Appendix VIIIa. Continued.

Date	Number "Entering" Birch River System				Total Number Entering	Number Removed From System			
		Tagged				Tagged		Untagged	
	Nets	Bracken Dam	Pyott's Crossing	Saskeram		River/Marsh	Bracken Dam	River/Marsh	Bracken Dam
13			8		8	4 (8)	1	25	
14			7		7	(9)	4	24	
15			5		5	2 (3)	2	30	1
16			9		9	5 (3)		18	
17			6	2	8	2 (4)	4	23	2
18		1	8	9	18	1 (7)	1	14	
19	1		8	14	23	1 (7)	1	10	
20				24	24	(8)	1		
21			20		20	(6)	3		
22				7	7	(3)	1		1
23			55		55	(10)	11		27
24		2	67	46	115	(19)	8		18
25		3	27	30	60	1 (14)			
26			21	25	46	2 (16)	1		3
27	11		26	16	53	10 (26)	14	1	7
28	8		24	28	60	(30)	16	3	14
29	10		46	24	80	(28)	12	5	28
30	4		14	32	50	1 (12)		3	
July									
1	5	1	11	15	32	3 (19)		3	
2		1	11	26	38	1 (20)			
3			11	3	14	(13)			
4		1	22	2	25	5 (7)			
5		1	25	10	36	1 (8)			
6			35	14	49	1 (11)			
7		6	44		50	(18)			
8				8	8	2 (2)			
9			16	1	17	1 (5)			
10							2		
11		2	6		8	3 (6)			
12						4			

Appendix VIIIa. Continued.

Date	Number "Entering" Birch River System				Total Number Entering	Number Removed From System			
		Tagged				Tagged		Untagged	
	Nets	Bracken Dam	Pyott's Crossing	Saskeram		River/Marsh	Bracken Dam	River/Marsh	Bracken Dam
13	1		12	2	15	3 (6)			
14			7		7	3 (4)			
15		1			1				
16		3	5		8	1 (2)			
17		3	6	1	10	(3)	1		
18		21	4	1	26				
19	17	5	11	2	35	2 (4)			
20		2	13		15	(6)			
21		1	15		16	3 (2)			
22			2	2	4				
23		6	6		12	(1)			
24		12	10		22	(2)			
25		7	17		24	1 (6)	1		
26		2	9		11	1 (1)			
27		4	8		12	1			
28		1	4		5	(1)	2		
29		1	6		7	3 (4)			
30			17		17				
31			15	2	17	(3)			
August									
1			18	1	19	(5)			
2			19		19	2 (10)			
3			26		26	8 (8)	1		
4			16		16	24 (9)			
5				2	2	17 (1)			
6			1		1	10 (3)			
7						2	1		
8						4			
9						1	1		
10									
11						4			
12						1			

Appendix VIIIa. Continued.

Date	Number "Entering" Birch River System				Total Number Entering	Number Removed From System			
		Tagged				Tagged		Untagged	
	Nets	Bracken Dam	Pyott's Crossing	Saskeram		River/Marsh	Bracken Dam	River/Marsh	Bracken Dam
13				5	5	(2)			
14									
15				8	8				
16				7	7				
17				8	8		1		
18				4	4		6		6
19						4			
20				11	11	1 (4)			
21				2	2				
22				12	12	(1)	1		
23	1				1				
24									
25									
26									
27									
28									
29									
30									
31									
September									
1									
2								2	
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Appendix VIIIa. Continied.

	Number "Entering" Birch River System				Total	Number Removed From System			
		Tagged			Number	Tagged		Untagged	
Date	Nets	Bracken Dam	Pyott's Crossing	Saskeram	Entering	River/Marsh	Bracken Dam	River/Marsh	Bracken Dam
13							1		
14									
15							1		2
16							1		
17									
18									
19							1		
20							1		15
21									
22									
23									
24									
25									
26									
27									
28							2		
29							1		
30							3		23
October									
1							4		
2							1		
3									
4									31
5									
6									
7									
8									
9									
10									
11									
12									
13									13

Appendix VIIIa. Continued.

Date	Number "Entering" Birch River System				Total Number Entering	Number Removed From System			
		Tagged				Tagged		Untagged	
	Nets	Bracken Dam	Pyott's Crossing	Saskeram		River/Marsh	Bracken Dam	River/Marsh	Bracken Dam
14							2		17
15							13		18
16							8		8
17							8		15
18							7		27
19							1		3
20									
21									
22									
23									
24									
25							2		6
26							3		17
27							2		10
28									5
29							2		11
30									
31									
November									
1									
2									
3									
4									
5									
6									
7									
8									1
9									1
10									
11									
12									1

Appendix VIIIa. Continued.

Date	Number "Entering" Birch River System				Total Number Entering	Number Removed From System			
		Tagged				Tagged		Untagged	
	Nets	Bracken Dam	Pyott's Crossing	Saskeram		River/Marsh	Bracken Dam	River/Marsh	Bracken Dam
13									4
14									2
15									
16									2
17									7
18									8
19									1
20									4
21									1
22									3
23									2
24									
25									2
26									
Totals	60	297 (10)	875	406	1648	174 (442)	164	623	380

Appendix VIIIb. Numbers of adult white suckers tagged, recaptured, released and removed from the Saskeram Marsh during May 15 - November 24 1983.

	Number "Entering" Birch River System				Total	Number Removed from System			
	Tagged				Number	Tagged		Untagged	
Date	Bracken Dam	Pyott's Crossing	Saskeram	Untagged	Entering	River/Marsh	Bracken Dam	River Marsh	Bracken Dam
May									
16	10			31	41				
17	42	1		57	100	(1)*			
18	26			50	76	(1)			
19	24	1			25				
20	15	8			23	(6)			
21	2				2	(4)			
22	6				6				
23	9	3			12	(3)			
24	6	1			7	(6)			
25						1 (1)		4	
26	28				28				4
27	26			5	31	(3)			
28	13			1	14				
29	4				4	(3)		1	3
30	3			1	4	(1)			
31	1				1				1
June									
2	1				1				1
3	1				1	1		1	
4	6				6	(2)			
5		4			4	(1)			
6	1	2			3	(4)			
7	1	3			4	(6)	(1)	1	5
8		6			6	(3)			1
9	4	4			8	3 (1)		5	
10		7			7	2 (9)	1		1
11	1	9			10	1 (7)	(8)	4	13
12	1	3			4	(2)	1	1	
13	3	6			9	2 (5)	1 (16)		
14		11			11	1 (11)	1 (33)		7

* Tagged white suckers re-released into system.

Appendix VIIIb. Continued.

Date	Number "Entering" Birch River System				Total Number Entering	Number Removed from System			
	Tagged					Tagged		Untagged	
	Bracken Dam	Pyott's Crossing	Saskeram	Untagged		River/Marsh	Bracken Dam	River Marsh	Bracken Dam
15	2	4			6	1 (10)	(13)		4
16		8			8	(8)	(5)	3	2
17	2	2	1		5	2 (7)	(7)	3	3
18		2	3		5	(5)	(12)	1	2
19	2	3	3		8	(6)	(2)		
20			3		3	(2)	1		
21		3			3	(4)	(2)		
22	1		2		3		(7)		
23						(4)	(4)		2
24						1 (4)	(14)		
25						1 (7)	(1)		
26		1			1		(2)		
27	1	1	1		3	(1)			
28	1				1		1 (3)		1
29		1			1	(4)			
30			1		1	(1)			
July									
1		5	5		10	(1)			
2		3	31		34	(2)			
3	3	6	4		13	(11)			
4		3			3	(3)			
5	2	13			16	(4)			
6		5	11		16	(2)			
7		4			4	(1)			
8			4		4	(1)			3
9		3	4	1	7	(2)			1
11		1			1				
12						1			7
13		1			1	(1)			
14									2

Appendix VIIIb. Continued.

	Number "Entering" Birch River System				Total Number Entering	Number Removed from System			
	Tagged					Tagged		Untagged	
Date	Bracken Dam	Pyott's Crossing	Saskeram	Untagged		River/Marsh	Bracken Dam	River Marsh	Bracken Dam
15	1				1				
16		1			1	(1)			
17		3			3				
18		4			4				
19		1			1				
20			1		1	(1)			
23	3				3				
27		2			2				
29	1				1				
30		1			1				
August									
1									1
2									1
3									1
21									1
September									
20									1
October									
15									1
17									1
19									4
25									19
26									8
27									19
28									41
29									34
30									55
31									2

Appendix VIIIb. Continued.

	Number "Entering" Birch River System				Total Number Entering	Number Removed from System			
	Tagged					Tagged		Untagged	
Date	Bracken Dam	Pyott's Crossing	Saskeram	Untagged		River/Marsh	Bracken Dam	River Marsh	Bracken Dam
November									
7									2
8									39
9									7
11									2
12									1
14									3
15									6
16									4
17									1
18									4
19									5
20									6
21									3
22									7
23									2
24									1
Totals	253	150	74	145	623	17 (175)	6 (128)	24	345

Appendix IXa. Schumacher-Eschemeyer population estimate calculations for adult northern pike in the lower Birch River, Saskeram Marshes, 1983.

Date	Number Caught C_t	Recaptures R_t	Number tagged (less removals)	Tagged fish at large M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2/C_t
May								
15	2	0	2	0	0	0	0	0
16	25	0	19	2	50	0	100	0
17	15	0	15	21	315	0	6615	0
18	25	0	22	36	900	0	32400	0
19	20	0	20	58	1160	0	67280	0
20	72	4	18	78	5616	312	438048	0.2222
21	46	4	16	96	4416	384	423936	0.3478
22	43	0	24	112	4816	0	539392	0
23	28	1	19	136	3808	136	517888	0.0357
24	25	4	12	155	3875	620	600625	0.6400
25	50	3	0	167	8350	501	1394450	0.1800
26	10	1	4	167	1670	167	278890	0.1000
27	11	0	6	171	1881	0	321651	0
28	22	0	18	177	3894	0	689238	0
29	23	1	9	195	6435	195	1254825	0.0303
30	44	2	12	204	8976	408	1831104	0.0909
31	18	0	2	216	3888	0	839808	0
June								
1	22	2	-1	216	4796	436	1045528	0.1818
2	25	1	0	217	5425	217	1177225	0.0400
3	24	2	1	217	5208	434	1130136	0.1667
4	23	0	1	218	5014	0	1093052	0
5	16	0	7	219	3504	0	767376	0
6	14	0	1	226	3164	0	715064	0
7	37	1	11	227	8399	227	1906573	0.0270
8	51	6	16	238	12138	1428	2888844	0.7059
9	31	4	5	254	7874	1016	1999996	0.5161

Appendix IXa. Continued.

Date	Number Caught C_t	Recaptures R_t	Number tagged (less removals)	Tagged fish at large M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2 / C_t
10	33	6	0	259	8547	1554	2213673	1.0909
11	40	9	11	259	10360	2331	2683240	2.0250
12	51	12	12	270	13770	3240	3717900	2.8235
13	46	13	3	282	12972	3666	3658104	3.6739
14	44	13	3	285	12540	3705	3573900	3.8409
15	43	7	1	288	12384	2016	3566592	1.1395
16	35	8	4	289	10115	2312	2923235	1.8286
17	43	10	2	293	12599	2930	3691507	2.3256
18	41	9	16	295	12095	2655	3568025	1.9756
19	42	9	21	311	13062	2799	4062282	1.9286
20	33	9	23	332	10956	2988	3637392	2.4545
21	29	9	17	355	10295	3195	3654725	2.7931
22	12	4	6	372	4464	1488	1660608	1.3333
23	103	21	44	378	38934	7938	14717052	4.2816
24	160	27	107	422	67520	11394	28493440	4.5562
25	75	15	59	529	39675	7935	20988075	3.0000
26	68	19	43	588	39984	11172	23510592	5.3088
27	111	50	29	631	70041	31550	44195871	22.5225
28	123	46	44	660	81180	30360	53578800	17.2033
29	153	40	68	704	107712	28160	75829248	10.4575
30	66	13	49	772	50952	10036	39334944	2.5606
July								
1	57	22	29	821	46797	18062	38420337	8.4912
2	59	21	37	850	50150	17850	42627500	7.4746
3	27	13	14	887	23949	11531	21242763	6.2593
4	37	12	20	901	33337	10812	30036637	3.8919
5	45	9	35	921	41445	8289	38170845	1.8000
6	61	12	48	956	58316	11472	55750096	2.3607

Appendix IXa. Continued.

Date	Number Caught C_t	Recaptures R_t	Number tagged (less removals)	Tagged fish at large M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2/C_t
7	68	18	50	1004	68272	18072	68545088	4.7647
8	12	4	6	1054	12648	4216	13330992	1.3333
9	23	6	16	1060	24380	6360	25842800	1.5652
10	2	2	-2	1076	2152	2152	2315552	2.0000
11	17	9	5	1074	18258	9666	19609092	4.7647
12	4	4	-4	1079	4316	4316	4656964	4.0000
13	24	9	12	1075	25800	9675	27735000	3.3750
14	14	7	4	1087	15218	7609	16541966	3.5000
15	1	0	1	1091	1091	0	1190281	0
16	11	3	7	1092	12012	3276	13117104	0.8182
17	14	4	9	1099	15386	4396	16909214	1.1429
18	26	0	26	1108	28808	0	31919264	0
19	41	6	33	1134	46494	6804	52724196	0.8780
20	21	6	15	1167	24507	7002	28599669	1.7143
21	21	5	13	1182	24822	5910	29339604	1.1905
22	4	0	4	1195	4780	0	5712100	0
23	13	1	12	1199	15587	1199	18688813	0.0769
24	24	2	22	1211	29064	2422	35196504	0.1667
25	32	8	22	1233	39456	9864	48649248	2.0000
26	13	2	10	1255	16315	2510	20475325	0.3077
27	13	1	11	1265	16445	1265	20802925	0.0769
28	8	3	3	1276	10208	3828	13025408	1.1250
29	14	7	4	1279	17906	8953	22901774	3.5000
30	17	0	17	1283	21811	0	27983513	0
31	20	3	17	1300	26000	3900	33800000	0.4500
August								
1	24	5	19	1317	31608	6585	41627736	1.0417
2	31	12	17	1334	41354	16008	55166236	4.6452

Appendix IXa. Continued.

Date	Number Caught C_t	Recaptures R_t	Number tagged (less removals)	Tagged fish at large M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2/C_t
3	43	17	17	1351	58093	22967	78483643	6.7209
4	49	33	-8	1368	67032	45144	91699776	22.2245
5	20	18	-15	1360	27200	24480	36992000	16.2000
6	14	13	-9	1345	18830	17602	25326350	12.0714
7	3	3	-3	1336	4008	4008	5354688	3.0000
8	4	4	-4	1333	5332	5332	7107556	4.0000
9	2	2	-2	1329	2658	2658	3532482	2.0000
10	0	0	0	1327	0	0	0	0
11	4	4	-4	1327	5308	5308	7043716	4.0000
12	1	1	-1	1323	1323	1323	1750329	1.0000
13	7	2	5	1322	9254	2644	12233788	0.5714
14	0	0	0	1327	0	0	0	0
15	8	0	8	1327	10616	0	14087432	0
16	7	0	7	1335	9345	0	12475575	0
17	9	1	7	1342	12078	1342	16208676	0.1111
18	16	6	-2	1349	21584	8094	29116816	2.2500
19	4	4	-4	1347	5388	5388	7257636	4.0000
20	16	5	10	1343	21488	6715	28858384	1.5625
21	2	0	2	1353	2706	0	3661218	0
22	14	2	11	1355	18970	2710	25704350	0.2857
23	1	0	1	1366	1366	0	1865956	0
24	0	0	0	1367	0	0	0	0
25	0	0	0	1367	0	0	0	0
26	0	0	0	1367	0	0	0	0
27	0	0	0	1367	0	0	0	0
28	0	0	0	1367	0	0	0	0
29	0	0	0	1367	0	0	0	0
30	0	0	0	1367	0	0	0	0
September								
1	2	0	0	1367	2734	0	3737378	0
2	0	0	0	1367	0	0	0	0
3	0	0	0	1367	0	0	0	0

Appendix IXb. Schumacher-Eschmeyer population estimate calculations for adult white suckers in the lower Birch River, Saskeram Marshes, 1983.

Date	Number Caught C_t	Recaptures R_t	Number tagged (less removals) M	Tagged fish at large M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2/C_t
May 16	41	0	10	0	0	0	0	0
17	101	1	44	10	1010	10	10100	.0099
18	77	1	27	54	4158	54	224532	.0129
19	25	0	25	81	2025	0	164052	0
20	29	6	29	106	3074	636	325844	1.2413
21	6	4	6	135	810	540	109350	2.6666
22	6	0	6	141	846	0	119286	0
23	15	3	15	147	2205	441	324135	0.6000
24	13	6	13	162	2106	972	341172	2.7692
25	6	2	1	175	1050	350	183750	0.6666
26	32	0	28	176	5632	0	991232	0
27	34	3	34	204	6936	612	1414944	0.2647
28	14	0	14	238	3332	0	793016	0
29	11	3	7	252	2772	756	698544	0.8181
30	5	1	5	259	1295	259	335405	0.2000
31	2	0	1	264	528	0	139392	0
June 2	2	2	1	265	530	530	140450	2.0000
3	3	1	1	266	798	266	212268	0.3333
4	8	2	8	267	2136	534	570312	0.5000
5	5	1	5	275	1375	275	378125	0.2000
6	7	4	7	280	1960	1120	548800	2.2857
7	17	7	9	287	4879	2009	1400273	2.8823
8	10	3	9	296	2960	888	876160	0.9000
9	17	4	9	305	5185	1220	1581425	0.9411
10	19	12	16	314	5966	3768	1873324	7.5789
11	43	16	17	330	14190	5280	4682700	5.9534
12	8	3	6	347	2776	1041	963272	1.1250
13	33	24	14	353	11649	8472	4112097	17.4545
14	64	46	22	367	23488	16882	8620096	33.0625

Appendix IXb. Continued.

Date	Number Caught C_t	Recaptures R_t	Number tagged (less removals) M	Tagged fish at large M_t	$C_t M_t$	$M_t R_t$	$C_t M_t^2$	R_t^2/C_t
15	34	24	16	389	13226	9336	5144914	16.9411
16	26	13	16	405	10530	5265	4264650	6.5000
17	27	16	12	421	11367	6736	4785507	9.4814
18	25	17	10	433	10825	7361	4687225	11.5600
19	16	8	14	443	7088	3544	3139984	4.0000
20	6	3	5	457	2742	1371	1253094	1.5000
21	9	6	7	462	4158	2772	1920996	4.0000
22	10	7	3	469	4690	3283	2199610	4.9000
23	10	8	4	472	4720	3776	2227840	6.4000
24	19	19	4	476	9044	9044	4304944	19.0000
25	9	9	7	483	4347	4347	2099601	9.0000
26	3	2	3	486	1458	972	708588	1.3333
27	4	1	4	490	1960	490	960400	0.2500
28	6	4	1	491	2946	1964	1446486	2.6666
29	5	4	5	496	2480	1984	1230080	3.2000
30	2	1	2	498	996	498	496008	0.5000
July 1	11	1	11	509	5599	509	2849891	0.0909
2	36	2	36	545	19620	1090	10692900	0.1111
3	24	11	24	569	13656	6259	7770264	5.0416
4	6	3	6	575	3450	1725	1983750	1.5000
5	20	4	20	595	11900	2380	7080500	0.8000
6	18	2	18	613	11034	1226	6763842	0.2222
7	8	1	5	618	4944	618	3055392	0.1250
8	6	1	5	623	3738	623	2328774	0.1666
9	9	2	9	632	5688	1264	3594816	0.4444
11	1	0	1	633	633	0	400689	0
12	8	1	0	633	5064	633	3205512	0.1250
13	2	1	2	635	1270	635	806450	0.5000
14	2	0	0	635	1270	0	806450	0

Appendix IXb. Continued.

Date	Number Caught C_t	Recaptures R_t	Number tagged (less removals) M	Tagged fish at large M_t	$C_t\ M_t$	$M_t\ R_t$	$C_t\ M_t^2$	R_t^2/C_t
15	1	0	1	636	636	0	404496	0
16	2	1	2	638	1276	638	814088	0.5000
17	3	0	3	641	1923	0	1232643	0
18	4	0	4	645	2580	0	1664100	0
19	1	0	1	646	646	0	417316	0
20	2	1	2	648	1296	648	839808	0.5000
23	3	0	3	651	1953	0	1271403	0
27	2	0	2	653	1306	0	852818	0
29	1	0	1	654	654	0	427716	0
30	1	0	1	655	655	0	429025	0

Appendix Xa. Summary of computations for Schumacher - Eschmeyer population estimates of adult northern pike in the Saskeram Marshes from May 15 through September 3. 1983.

Time Period	ΣC_t	ΣR_t	ΣM	ΣM_t	$\Sigma(C_t M_t)$	$\Sigma(M_t R_t)$	$\Sigma(C_t M_t^2)$	$\Sigma(R_t^2 C_t)$
May 15-31	489	20	218	1,991	60,050	2,723	9,236,250	1.6469
May 15-June 30	2083	385	821	12,599	755,729	179,905	365,219,249	102.4079
May 15-July 31	2826	584	1317	46,813	1,531,459	381,316	1,191,079,823	171.4356
May 15-Aug. 23	3105	716	1369	77,629	1,907,000	559,624	1,696,634,166	257.12
May 15-Sept. 3	3107	716	1369	92,666	1,909,734	559,624	1,700,371,544	257.12

Appendix Xb. Summary of computations for Schumacher - Eschmeyer population estimates of adult white suckers in the Saskeram Marshes from May 15 through July, 1983.

Time Period	$\Sigma\ C_t$	$\Sigma\ R_t$	$\Sigma\ M$	$\Sigma\ M_t$	$\Sigma(C_tM_t)$	$\Sigma(M_tR_t)$	$\Sigma(C_tM_t^2)$	$\Sigma(R_t^2\ C_t)$
May 16-31	417	30	265	2,505	37,779	4,630	6,174,754	9.2493
May 16-June 30	864	297	502	7,738	208,248	109,658	78,133,983	185.6984
May 16-July 31	1035	328	659	22,020	309,039	127,906	137,826,626	195.8252

Appendix XIa. Age specific mean lengths, weights and condition factors for all pike May, 1983 to January, 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
0	328	32.48	252.69	132.94	0.80	256	46.89	258.01	139.41	0.78	853	41.73	218.87	100.73	0.79
1	12	1.19	330.75	321.97	0.74	4	0.73	327.50	243.70	0.71	19	0.93	310.00	268.44	0.75
2	148	14.65	442.41	627.95	0.71	120	21.98	464.45	687.24	0.68	300	14.68	446.27	636.04	0.70
3	175	17.33	482.70	868.15	0.76	63	11.54	482.81	837.86	0.73	309	15.12	476.76	823.84	0.74
4	175	17.33	502.51	989.60	0.77	50	9.16	517.22	1108.32	0.77	304	14.87	500.84	985.09	0.76
5	107	10.59	507.95	1068.92	0.80	31	5.68	502.55	1061.16	0.83	159	7.78	510.77	1103.40	0.82
6	40	3.96	526.80	1164.75	0.79	9	1.65	562.44	1416.89	0.77	51	2.50	533.31	1215.29	0.79
7	8	0.79	529.25	1285.00	0.86	6	1.10	598.50	1780.00	0.83	14	0.68	558.93	1497.14	0.84
8	1	0.10	534.00	1120.00	0.74	-	-	-	-	-	1	0.05	534.00	1120.00	0.74
9	2	0.20	596.00	1790.00	0.81	-	-	-	-	-	2	0.10	596.00	1790.00	0.81
Unknown	14	1.39	487.29	937.14	0.81	7	1.28	508.86	1241.43	0.84	32	1.57	490.59	1014.06	0.82
Total	1010	100.00	408.85	648.10	0.77	546	100.00	379.43	535.48	0.75	2044	100.00	371.67	553.52	0.77

Appendix XIb. Age specific mean lengths, weights and condition factors for pike May - June, 1983.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
1	4	0.60	409.50	475.00	0.62	1	0.37	330.00	320.00	0.89	5	0.47	393.60	444.00	0.68
2	141	21.27	444.08	626.74	0.71	111	40.81	465.87	681.80	0.67	264	24.65	450.60	643.64	0.70
3	173	26.09	482.97	867.85	0.76	60	22.06	483.17	845.00	0.74	273	25.49	480.96	854.79	0.75
4	174	26.24	502.87	992.99	0.77	48	17.65	517.73	1106.25	0.76	272	25.40	505.28	1022.32	0.77
5	106	15.99	507.84	1068.21	0.80	31	11.40	502.55	1061.16	0.83	158	14.75	510.72	1103.14	0.82
6	40	6.03	526.80	1164.75	0.79	9	3.31	562.44	1418.89	0.77	51	4.76	533.31	1215.29	0.79
7	8	1.21	529.25	1285.00	0.86	5	1.84	603.80	1828.00	0.83	13	1.21	557.92	1493.85	0.85
8	1	0.15	534.00	1120.00	0.74	-	-	-	-	-	1	0.09	534.00	1120.00	0.74
9	2	0.30	596.00	1790.00	0.81	-	-	-	-	-	2	0.09	596.00	1790.00	0.81
Unknown	14	2.11	487.29	937.14	0.81	7	2.57	508.86	1241.43	0.84	32	2.99	490.59	1014.06	0.82
Total	663	100.00	487.16	906.65	0.76	272	100.00	489.36	894.47	0.73	1071	100.00	487.62	911.68	0.76

Appendix XIc. Age specific lengths, weights and condition factors for all pike July - September, 1983.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
0	215	71.91	281.94	184.27	0.77	176	63.31	289.25	192.60	0.75	515	73.05	261.85	156.17	0.77
1	40	13.38	440.55	727.78	0.83	38	13.67	457.11	790.66	0.82	81	11.49	445.83	745.88	0.83
2	23	7.69	510.52	1094.35	0.81	37	13.31	541.38	1303.19	0.81	60	8.51	529.55	1223.13	0.81
3	15	5.02	569.73	1590.00	0.84	21	7.55	622.76	2012.29	0.81	37	5.25	600.38	1828.86	0.82
4	5	1.67	596.40	1724.00	0.77	3	1.08	690.00	2560.00	0.73	8	1.13	631.50	2037.50	0.75
5	-	-	-	-	-	2	0.72	820.00	4840.00	0.87	2	0.28	820.00	4840.00	0.87
Unknown	1	0.33	544.00	1275.00	0.79	1	0.36	570.00	1300.00	0.70	2	0.28	557.00	1287.50	0.75
Total	299	100.00	341.32	426.90	0.79	278	100.00	380.10	622.59	0.77	705	100.00	330.15	440.36	0.78

Appendix XId. Age specific mean lengths, weights and condition factors for pike October, 1983 - January, 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
0	312	96.89	251.73	131.91	0.80	245	97.61	257.15	138.41	0.78	558	97.21	254.17	134.85	0.79
1	7	2.17	299.00	263.73	0.78	2	0.80	275.00	157.40	0.76	9	1.57	293.67	240.10	0.77
2	1	0.31	242.00	94.80	0.67	1	0.40	448.00	726.00	0.81	2	0.35	345.00	410.40	0.74
3	1	0.31	425.00	688.00	0.90	1	0.40	480.00	925.00	0.84	2	0.35	452.50	806.50	0.87
4	-	-	-	-	-	2	0.80	505.00	1158.00	0.90	2	0.35	505.00	1158.00	0.90
5	1	0.31	520.00	1144.00	0.81	-	-	-	-	-	1	0.17	520.00	1144.00	0.81
Total	322	100.00	254.10	139.53	0.80	251	100.00	260.92	152.16	0.78	574	100.00	257.13	145.13	0.79

Appendix XIIa. Age specific mean lenths, weights and condition factors for all pike April - October 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
0	319	59.40	289.78	196.91	0.77	273	62.23	296.44	203.21	0.75	716	64.91	274.71	174.87	0.76
1	44	8.19	434.98	707.07	0.83	43	9.82	451.86	772.67	0.83	90	8.16	440.99	728.84	0.83
2	40	7.45	494.35	992.25	0.79	52	11.87	531.67	1218.42	0.80	92	8.34	515.45	1120.09	0.80
3	48	8.94	515.67	1142.92	0.79	31	7.08	611.23	1926.71	0.81	80	7.25	553.63	1451.85	0.79
4	39	7.26	546.44	1303.85	0.75	18	4.11	618.89	1962.78	0.74	57	5.17	569.32	1511.93	0.75
5	34	6.33	532.38	1110.59	0.72	15	3.42	626.07	2132.00	0.77	49	4.44	561.06	1423.27	0.74
6	12	2.23	566.33	1342.50	0.73	3	0.68	605.33	2313.33	1.06	15	1.36	574.13	1536.67	0.79
7	-	-	-	-	-	1	0.23	692.00	2500.00	0.75	1	0.09	692.00	2500.00	0.75
8	-	-	-	-	-	1	0.23	614.00	1320.00	0.57	1	0.09	614.00	1320.00	0.57
Unknown	1	0.19	544.00	1275.00	0.79	1	0.23	570.00	1300.00	0.70	2	0.18	557.00	1287.50	0.75
Total	537	100.00	377.76	548.36	0.77	438	100.00	390.81	664.74	0.77	1103	100.00	361.80	539.76	0.77

Appendix XIIb. Age specific mean lengths, weights and condition factors for all pike April - June 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
1	2	1.68	316.00	260.00	0.82	4	8.51	385.00	535.00	0.92	6	3.61	362.00	443.33	0.89
2	12	10.08	453.08	750.00	0.77	9	19.15	481.78	873.33	0.77	21	12.65	465.38	802.86	0.77
3	29	24.37	480.21	844.48	0.74	6	12.77	520.00	1123.33	0.78	35	21.08	487.03	892.29	0.75
4	30	25.21	518.97	1030.00	0.73	11	23.40	550.73	1274.55	0.73	41	24.70	527.49	1095.61	0.73
5	34	28.57	532.38	1110.59	0.72	12	25.53	577.58	1476.67	0.75	46	27.71	544.17	1206.09	0.73
6	12	10.08	566.33	1342.50	0.73	3	6.38	605.33	2313.33	1.06	15	9.04	574.13	1536.67	0.79
7	-	-	-	-	-	1	2.13	692.00	2500.00	0.75	1	0.60	692.00	2500.00	0.75
8	-	-	-	-	-	1	2.13	614.00	1320.00	0.57	1	0.60	614.00	1320.00	0.57
Total	119	100.00	508.08	998.15	0.74	47	100.00	534.19	1260.43	0.79	166	100.00	515.47	1072.41	0.75

Appendix XIIc. Age specific lengths, weights and condition factors for all pike July - September, 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
0	16	64.00	271.31	153.01	0.76	11	47.83	277.18	161.62	0.76	295	73.93	152.11	36.19	0.80
1	1	4.00	238.00	117.50	0.87	1	4.35	430.00	340.00	0.43	5	1.25	255.80	143.88	0.77
2	6	24.00	436.67	745.42	0.81	8	34.78	446.75	757.88	0.79	34	8.52	418.56	590.56	0.74
3	1	4.00	494.00	1100.00	0.91	2	8.70	473.50	580.00	0.54	34	8.52	444.41	576.35	0.63
4	1	4.00	440.00	400.00	0.47	-	-	-	-	-	30	7.52	460.30	636.00	0.64
7	-	-	-	-	-	1	4.35	572.00	1540.00	0.82	1	0.25	572.00	1540.00	0.82
Total	25	100.00	325.32	341.53	0.77		100.00	372.70	473.08	0.74	399	100.00	225.25	179.66	0.77

Appendix XIII. Growth in fork length of young-of-the-year northern pike in the Saskeram Marshes during biweekly periods in 1983 and 1984.

	1983		1984	
Period	n	Mean length ± 2 SE (mm)	n	Mean length ± 2 SE (mm)
July 1-15	146	126.94 ± 31.74	55	166.87 ± 32.10
July 16-31	55	141.95 ± 24.94	66	194.38 ± 43.00
Aug. 1-15	51	155.25 ± 31.16	149	239.97 ± 41.12
Aug. 16-31	16	196.06 ± 78.24	49	262.92 ± 59.88
Sept. 1-15	30*	272.53 ± 29.02	81	296.72 ± 58.70
Sept.16-30	0		153	310.14 ± 54.14
Oct. 1-15	87	265.24 ± 32.72	101	307.32 ± 48.92
Oct. 16-31	50	258.16 ± 35.57	100	308.03 ± 40.44
Nov. 1-15	51	253.94 ± 47.22	101	308.42 ± 53.14
Nov. 16-30	79	258.35 ± 38.20		
Dec. 6	209	249.76 ± 38.84		
Jan. 17/84	50*	296.70 ± 37.92		

* Samples caught by 3.81 cm gillnet, which selected for larger - sized fish.

Appendix XIVa. Age specific mean lengths, weights and condition factors for walleye, May 1983.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
5	1	1.12	405.00	800.00	1.20	-	-	-	-	-	1	0.93	405.00	800.00	1.20
6	30	33.71	390.17	818.67	1.37	4	21.05	452.00	1235.00	1.34	34	31.48	397.44	867.65	1.37
7	35	39.33	407.94	909.43	1.34	9	47.37	447.33	1130.00	1.26	44	40.71	416.00	954.55	1.32
8	15	16.85	411.67	996.67	1.43	4	21.05	460.00	1305.00	1.34	19	17.59	421.84	1061.58	1.41
9	8	8.99	417.13	965.00	1.33	1	5.26	455.00	1200.00	1.27	9	8.33	421.33	991.11	1.33
10	-	-	-	-	-	1	5.26	490.00	1600.00	1.36	1	0.93	490.00	1600.00	1.36
Total	89	100.00	403.00	897.30	1.36	19	100.00	453.63	1217.37	1.30	108	100.00	412.21	953.61	1.35

Appendix XIVb. Age specific mean lengths, weights and condition factors for walleye, May, 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
6	2	9.52	385.00	670.00	1.18	-	-	-	-	-	2	7.14	385.00	670.00	1.18
7	2	9.52	405.00	750.00	1.13	-	-	-	-	-	2	7.14	405.00	750.00	1.13
8	9	42.86	435.56	997.78	1.21	3	42.86	420.00	1026.67	1.38	12	42.86	431.67	1005.00	1.25
9	5	23.81	424.00	968.00	1.27	4	57.14	462.50	1305.00	1.31	9	32.14	441.11	1117.78	1.28
10	2	9.52	480.00	1420.00	1.27	-	-	-	-	-	2	7.14	480.00	1420.00	1.27
Unknown	1	4.76	420.00	910.00	1.23	-	-	-	-	-	1	3.57	420.00	910.00	1.23
Total	21	100.00	428.57	971.90	1.22	7	100.00	444.29	1185.71	1.34	28	100.00	432.50	1025.36	1.25

Appendix XV. Age specific mean lengths, weights and condition factors for white suckers April - May, 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
2	1	2.63	304.00	480.00	1.71	-	-	-	-	-	1	1.04	304.00	480.00	1.71
3	1	2.63	440.00	1200.00	1.41	-	-	-	-	-	1	1.04	440.00	1200.00	1.41
4	2	5.26	380.00	730.00	1.22	2	3.77	380.00	840.00	1.50	5	5.21	392.00	764.00	1.25
5	6	15.79	397.33	973.33	1.53	3	5.66	354.67	693.33	1.50	10	10.42	381.80	872.00	1.53
6	3	7.89	435.33	1300.00	1.57	5	9.43	436.40	1374.00	1.64	8	8.33	436.00	1346.25	1.62
7	5	13.16	452.80	1400.00	1.50	9	16.98	491.22	1975.33	1.65	14	14.58	477.50	1769.86	1.59
8	7	18.42	460.86	1545.71	1.57	12	22.64	490.83	1958.33	1.64	22	22.92	473.09	1721.82	1.60
9	4	10.53	452.50	1400.00	1.50	13	24.53	506.15	2038.46	1.57	17	17.71	493.53	1888.24	1.56
10	6	15.79	460.33	1558.33	1.57	6	11.32	503.00	2073.33	1.61	12	12.50	481.67	1815.83	1.59
11	1	2.63	470.00	1540.00	1.48	3	5.66	507.33	2186.67	1.68	4	4.17	498.00	2025.00	1.63
12	2	5.26	459.00	1520.00	1.57	-	-	-	-	-	2	2.08	459.00	1520.00	1.57
Total	38	100.00	438.00	1321.84	1.53	53	100.00	479.94	1837.89	1.61	96	100.00	460.24	1590.40	1.56

Appendix XVIa. Age specific mean lengths, weights and condition factors for carp, June 1983.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
9	1	2.78	630.00	7500.00	3.00	3	10.34	708.33	9820.00	2.72	4	5.88	688.75	9240.00	2.79
10	4	11.11	665.00	7500.00	2.58	5	17.24	692.40	8456.00	2.52	9	13.24	680.22	8031.11	2.55
11	7	19.44	667.86	7042.86	2.38	4	13.79	679.50	8092.50	2.54	11	16.18	672.09	7424.55	2.44
12	1	2.78	670.00	6060.00	2.01	2	6.90	717.50	9050.00	2.45	3	4.41	701.67	8053.33	2.30
13	4	11.11	665.75	6160.00	2.11	5	17.24	726.00	7756.00	2.05	10	14.71	690.30	6792.00	2.07
14	4	11.11	697.75	7655.00	2.24	2	6.90	695.00	7710.00	2.33	7	10.29	705.00	7960.00	2.27
15	4	11.11	718.75	8670.00	2.32	2	6.90	712.50	7275.00	1.95	6	8.82	716.67	8205.00	2.20
16	1	2.78	693.00	6600.00	1.98	1	3.45	755.00	7740.00	1.80	2	2.94	724.00	7170.00	1.89
17	-	-	-	-	-	1	3.45	745.00	11700.00	2.83	1	1.47	745.00	11700.00	2.83
18	1	2.78	705.00	7200.00	2.05	-	-	-	-	-	1	1.47	705.00	7200.00	2.05
20	1	2.78	705.00	8800.00	2.51	-	-	-	-	-	1	1.47	705.00	8800.00	2.51
Unknown	8	22.22	668.88	6192.50	2.03	4	13.79	668.25	7542.50	2.48	13	19.12	663.77	6554.62	2.20
Total	36	100.00	678.28	7081.67	2.26	29	100.00	702.00	8295.52	2.39	68	100.00	687.43	7576.32	2.31

Appendix XVIb. Age specific mean lengths, weights and condition factors for all carp May - June, 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
11	1	5.56	610.00	4860.00	2.14	1	20.00	750.00	9500.00	2.25	2	8.33	680.00	7180.00	2.20
13	3	16.67	656.67	5533.33	1.94	1	20.00	780.00	6740.00	1.42	4	16.67	687.50	5835.00	1.81
14	2	11.11	730.00	7915.00	2.04	-	-	-	-	-	2	8.33	730.00	7915.00	2.04
15	1	5.56	620.00	6700.00	2.81	1	20.00	830.00	6700.00	1.17	3	12.50	710.00	6560.00	1.99
16	4	22.22	690.00	6250.00	1.90	2	40.00	725.00	8600.00	2.28	6	25.00	701.67	7033.33	2.03
17	4	22.22	700.00	7100.00	2.06	-	-	-	-	-	4	16.67	700.00	7100.00	2.06
18	1	5.56	710.00	6400.00	1.79	-	-	-	-	-	1	4.17	710.00	6400.00	1.79
19	1	5.56	760.00	8200.00	1.87	-	-	-	-	-	1	4.17	760.00	8200.00	1.87
Unknown	1	5.56	680.00	5900.00	1.88	-	-	-	-	-	1	4.17	680.00	5900.00	1.88
Total	18	100.00	687.22	6549.44	2.01	5	100.00	762.00	8028.00	1.88	24	100.00	702.50	6846.25	1.98

Appendix XVII. Age specific mean lengths, weights and condition factors for goldeye, September - October, 1984.

	Males					Females					All Sex				
Age	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor	n	Frequency (%)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
1	-	-	-	-	-	-	-	-	-	-	1	10.00	200.00	65.00	0.81
3	-	-	-	-	-	-	-	-	-	-	1	10.00	290.00	249.00	1.02
4	6	100.00	322.17	343.33	1.03	1	100.00	310.00	340.00	1.14	8	80.00	320.38	346.88	1.06
Total	6	100.00	322.17	343.33	1.03	1	100.00	310.00	340.00	1.14	10	100.00	305.30	308.90	1.03

Appendix XVIIIa. Summary of growth parameters of northern pike sampled at the following areas during 1983.

Bracken Dam

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May	All	206	4.60	511.05	1131.3	0.83
	Male	170	4.36	504.74	1080.29	0.83
	Female	30	4.92	549.37	1477.67	0.86
June	All	37	3.75	509.43	995.68	0.72
	Male	21	4.00	521.29	1069.05	0.74
	Female	7	3.42	517.14	1077.14	0.74
July	All	229	1.10	239.59	213.00	0.75
	Male	1	4.00	440.00	400.00	0.47
	Female	2	2.00	447.50	390.00	0.44
Aug.	All	4	0.50	207.00	86.43	0.76
	Male	-	-	-	-	-
	Female	-	-	-	-	-
Sept.	All	30	0.16	272.53	155.30	0.76
	Male	18	0.16	269.72	151.57	0.77
	Female	12	0.16	276.75	160.90	0.76
Oct.	All	136	0.06	262.35	138.22	0.76
	Male	82	0.08	260.26	137.07	0.77
	Female	54	0.03	265.52	139.98	0.74
Nov.	All	171	0.00	241.19	106.45	0.72
	Male	100	0.01	239.63	104.21	0.72
	Female	71	0.00	243.38	109.61	0.71
Dec.	All	210	0.00	249.90	136.88	0.86
	Male	116	0.00	249.23	138.32	0.88
	Female	93	0.00	250.37	134.62	0.84

Saskeram Lake Outlet

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May	All	201	3.30	474.65	806.70	0.74
	Male	127	3.40	476.91	828.27	0.75
	Female	74	3.13	470.77	769.68	0.73
June	All	237	2.98	480.18	834.68	0.73
	Male	151	3.17	480.23	849.80	0.75
	Female	83	2.64	479.92	801.93	0.71
Aug.	All	5	0.00	238.80	110.56	0.81
	Male	-	-	-	-	-
	Female	-	-	-	-	-

Appendix XVIIIa. Continued.

Saskeram Lake (to Jan., 1984).

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May	All	45	2.48	477.33	660.89	0.60
	Male	28	2.50	475.00	642.86	0.59
	Female	17	2.47	481.18	690.59	0.61
June	All	5	2.60	480.80	752.00	0.67
	Male	2	3.50	490.00	815.00	0.68
	Female	3	2.00	474.67	710.00	0.66
July	All	20	1.75	372.30	629.78	0.84
	Male	5	2.50	470.80	890.00	0.83
	Female	8	2.62	484.25	931.25	0.80
Jan.	All	57	0.38	319.18	308.00	0.82
	Male	24	0.37	316.88	301.00	0.83
	Female	33	0.39	320.85	313.09	0.82

Pyott's Crossing - Lower Birch River

May	All	25	3.36	464.40	862.80	0.81
	Male	17	3.29	451.94	790.59	0.81
	Female	4	3.75	444.00	727.50	0.82
June	All	314	3.49	486.97	925.47	0.77
	Male	147	3.36	484.31	873.66	0.74
	Female	54	3.24	499.15	946.85	0.73
July	All	49	0.10	150.78	54.07	0.79
	Male	1	2.00	484.00	960.00	0.85
	Female	1	3.00	482.00	720.00	0.64
Aug.	All	62	0.03	160.90	33.91	0.79
	Male	-	-	-	-	-
	Female	-	-	-	-	-

Appendix XVIIIb. Summary of growth parameters of northern pike sampled at the following areas during 1984.

Bracken Dam

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
April	All	149	4.12	520.06	1088.99	0.74
	Male	111	4.08	508.41	993.15	0.73
	Female	38	4.26	554.08	1368.95	0.77
July	All	70	0.45	240.54	242.35	0.77
	Male	8	2.38	477.50	932.50	0.75
	Female	4	1.00	505.00	1140.00	0.89
Aug.	All	116	0+	248.44	114.69	0.73
	Male	59	0+	250.80	118.05	0.73
	Female	46	0+	250.00	114.85	0.72
Sept.	All	326	0.68	379.12	600.86	0.79
	Male	160	0.53	356.19	477.77	0.80
	Female	166	0.80	401.22	719.51	0.77

Lower Birch River

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
July	All	56	0+	194.05	62.42	0.82
Aug.	All	27	0+	231.48	92.94	0.72
	Male	16	0+	231.25	92.22	0.71
	Female	8	0+	237.50	99.50	0.73

Saskeram Lake

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May	All	7	2.24	468.57	820.00	0.77
	Male	3	3.33	497.33	946.67	0.77
	Female	4	1.75	447.00	725.00	0.78
June	All	10	2.00	479.90	1002.00	0.89
	Male	5	2.40	507.00	1140.00	0.86
	Female	5	1.60	452.80	864.00	0.91
Aug.	All	110	0.96	421.74	711.83	0.83
	Male	56	0.86	406.18	630.36	0.83
	Female	54	1.07	437.87	796.31	0.83

Cumberland Marshes

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
August	All	31	0+	293.39	204.55	0.81
	Male	17	0+	292.35	202.35	0.81
	Female	14	0+	294.64	207.21	0.81
October	All	131	0+	358.85	334.55	0.71

Appendix XIXa. Summary of growth parameters of white suckers sampled at the following areas during 1983.

Bracken Dam

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May	All	244	-	444.18	1513.98	1.67
	Male	94	-	438.16	1410.64	1.66
	Female	116	-	462.61	1734.22	1.72
June	All	49	-	427.12	1189.14	1.42
	Male	15	-	445.13	1326.67	1.49
	Female	20	-	467.60	1467.50	1.40
July	All	23	1.28	211.39	285.26	1.47
Oct.	All	32	1.17	213.97	139.76	1.39

Pyott's Crossing - Lower Birch River

May	All	14	-	472.86	2027.86	1.89
	Male	4	-	426.25	1435.00	1.82
	Female	10	-	491.50	2265.00	1.91
June	All	80	-	436.03	1374.75	1.54
	Male	11	-	433.45	1307.27	1.60
	Female	22	-	477.32	1682.73	1.49

Saskeram Lake Outlet

June	All	16	-	335.19	557.50	1.36
	Male	3	-	331.33	540.00	1.44
	Female	7	-	314.29	430.00	1.22

Appendix XIXb. Summary of growth parameters of white suckers sampled at Bracken Dam during 1984.

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
April - May	All	96	7.68	460.24	1590.40	1.56
	Male	38	7.44	438.00	1321.84	1.54
	Female	53	7.96	479.94	1837.89	1.61
August	All	97	-	312.09	483.30	1.58
	Male					
	Mature	33	-	313.45	500.76	1.62
	Immature	18	-	314.11	495.00	1.59
	Female					
	Mature	13	-	317.08	491.92	1.54
	Immature	8	-	307.67	456.06	1.56
Sept.- Oct.	All	13	-	359.15	740.62	1.49
	Male	1	-	330.00	610.00	1.70
	Female	4	-	362.50	705.00	1.45
	Unknown	8	-	361.12	774.75	1.48

Appendix XXa. Summary of growth parameters of walleyes sampled at Bracken Dam during 1983.

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May	All	108	7.03	412.21	953.61	1.35
	Male	89	6.98	403.37	897.30	1.36
	Female	19	7.26	453.63	1217.37	1.30

Appendix XXb. Summary of growth parameters of walleyes sampled at Bracken Dam during 1984.

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May	All	28	8.25	432.50	1025.36	1.25
	Male	21	8.15	428.57	971.90	1.22
	Female	7	8.57	444.29	1185.71	1.34

Appendix XXIa. Summary of growth parameters of carp sampled at Bracken Dam during 1983.

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
June	All	68	12.50	687.43	7576.32	2.31
	Male	28	12.85	678.28	7081.67	2.26
	Female	25	12.04	702.00	8295.52	2.39

Appendix XXIb. Summary of growth parameters of carp sampled at Bracken Dam during 1984.

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
May - June	All	24	15.13	702.50	6846.25	1.98
	Male	17	15.4	687.22	6549.44	2.01
	Female	5	14.2	762.00	8028.00	1.88

Appendix XXII. Summary of growth parameters of goldeyes sampled at Bracken Dam during 1984.

Month	Sex	n	Mean Age (Years)	Mean Length (mm)	Mean Weight (g)	Mean Condition Factor
Sept. - Oct.	All	10	3.60	305.30	308.90	1.03
	Male	6	4.00	322.17	343.33	1.03
	Female	1	4.00	310.00	340.00	1.14

Appendix XXIII. Incremental growth in fork length of individual pike tagged in 1983.

Age at Tagging	Fork Length (cm) at Tagging	Fork Length (cm) at Recapture	Days at Large	Increments (cm) Total	Increments (cm) Per Day
2	44.0	45.0	271	1.0	0.0036
3	48.5	52.0	337	3.5	0.01
	45.8	51.0	277	5.2	0.02
	39.0	48.0	281	9.0	0.03
Mean	44.4	50.3	298	5.9	0.02
4	51.5	55.0	341	3.5	0.01
	46.0	51.0	337	5.0	0.01
	49.0	53.0	311	4.0	0.01
	41.5	48.0	309	6.5	0.02
	41.0	47.0	360	6.0	0.02
Mean	45.8	50.8	331	5.0	0.014
5	51.0	52.0	432	1.0	0.002
	50.0	50.0	353	-	-
	52.0	52.0	306	-	-
Mean	51.0	51.3	363	0.33	0.0009
6	53.0	57.0	338	4.0	0.01
	52.5	55.0	450	2.5	0.006
Mean	52.7	56.0	394	3.25	0.008

Appendix XXIV. Incremental growth in fork length of individual white suckers tagged in 1983.

Fork Length (cm)		Days at	Increments (cm)	
at Tagging	at Recapture	Large	Total	Per Day
28.6	30.0	328	1.4	0.004
30.3	34.0	363	3.7	0.01
34.0	38.0	396	4.0	0.01
40.5	42.0	357	1.5	0.004
41.6	45.0	340	3.4	0.01
42.0	44.0	329	2.0	0.006
42.8	45.0	340	2.2	0.006
44.0	45.0	317	1.0	0.003
44.0	45.0	337	1.0	0.002
44.0	45.0	338	1.0	0.003
44.0	44.0	343	-	-
45.0	45.0	335	-	-
45.5	46.0	340	0.5	0.001
46.3	49.0	345	2.7	0.008
49.2	50.0	340	0.8	0.002
49.5	50.0	315	0.5	0.001
49.5	50.0	338	0.5	0.001
50.0	51.0	341	1.0	0.003
51.0	51.0	342	-	-
52.0	52.0	316	-	-
Mean				
43.7	45.0	340	1.4	0.004

Appendix XXV. Incremental growth in fork length of individual walleyes tagged in 1983.

Age at Tagging	Fork Length (cm) at Tagging	Fork Length (cm) at Recapture	Days at Large	Increments (cm) Total	Increments (cm) Per Day
7	45.0	49.0	349	4.0	0.01
9	41.5	45.0	356	3.5	0.0098
10	72.0	75.0	374	3.0	0.008

Appendix XXVIa. Maturity schedules for Saskeram Marshes pike, May, 1983 - January, 1984. Percentages in parentheses.

	Males		Females		Both Sexes	
Age	Immature	Mature	Immature	Mature	Immature	Mature
0	328		256		584	
1	9	3 (25)	4		13	3 (18.8)
2	3	140 (98)	1	119 (99)	4	259 (98.5)
3		174 (100)		63 (100)		237 (100)
4		174		49		223
5		107		31		138
6		39		9		48
7		8		6		14
8		1				1
9		2				2

Calculations using Abrasov's (1967) method.

Mean age of ♂ maturity $= \underline{1(25) + 2(98-25) + 3(100-98)} = \frac{177}{100} = 1.77$ years

Mean age of ♀ maturity $= \frac{2(99) + 3(100-99)}{99 + (100-99)} = \frac{201}{100} = 2.01$ years

Mean age of maturity
sexes combined $= \frac{1(18.8) + 2(98.5 - 18.8) + 3(100-98.5)}{18.8 + (98.5-18.8) + (100-98.5)} = \frac{182.7}{100} = 1.83$ years

Appendix XXVIb. Maturity schedules for Saskeram Marshes pike, April -October **1984. Percentages in parentheses.**

	Males		Females		Both Sexes	
Age	Immature	Mature	Immature	Mature	Immature	Mature
0	319		272	1 (0.4)	591	1 (.02)
1	5	39 (89)	2	41 (95)	7	80 (92)
2	1	39 (98)		52 (100)	1	91 (99)
3		48 (100)		31		79 (100)
4		39		18		57
5		34		15		49
6		12		3		15
7				1		1
8				1		1

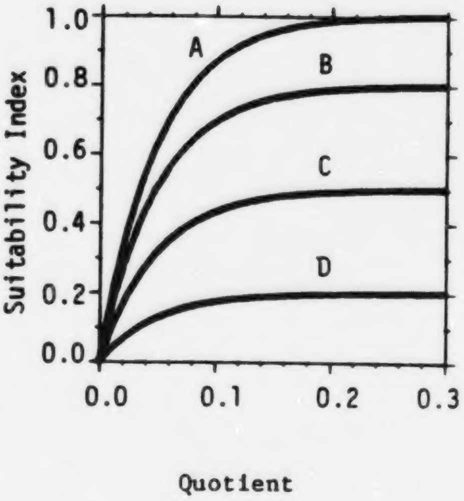
Calculations using Abrasov's (1967) method.

Mean age ♂ maturity = $\underline{1(89) + 2(98-89) + 3(100-98)}$ = 1.13 years

Mean age of ♀ Maturity = $\dfrac{0(0.4) + 1(95-0.4) + 2(100-95)}{0.4 + (95-0.4) + (100-95)}$ = 1.05 years

Mean age of maturity
sexes combined = $\dfrac{0(0.2) + 1(92-0.2) + 2(99-92) + 3(100-99)}{0.2 + 992-0.2) + (99-92) + (100-99)}$ = 1.09 years

Appendix XXVII. Suitability Index graphs for the lacustrine HSI model variables for northern pike (from Inskip 1982).

Variable		Suitability graph
V_1	Ratio of spawning habitat to summer habitat (area that is less than 1 m deep and vegetated (spring), divided by total midsummer area).	

Use the appropriate curve, according to the density of vegetation or plant debris within the area included as spawning habitat. Do not include areas covered with filamentous algae, living or dead, as suitable spawning habitat.

A. Vegetation obscures most (>80%) of the bottom; plant material dense throughout the 15 cm of the water column above the substrate. When submersed, plant material not tightly compacted. Vegetation provides extensive surface area to which eggs may adhere, abundant cover for eggs and fry, and allows for circulation of water around the eggs (e.g. flooded sedge or grass meadow).

B. Plant growth less lush than in A, but covers much of the substrate and occupies much of water column directly above the sediments. More than 60% of the bottom obscured in vertical projection from depth of 15 cm above the bottom. Plant material not compacted when under water.

C. Vegetation or debris covers much of the bottom, but plant material does not occupy much of the water column immediately above the substrate. This category may include compacted vegetation, branches of woody plants, and leaves of deciduous trees.

D. Thinly scattered vegetation or debris only. Would provide little, if any, shelter for eggs and fry.

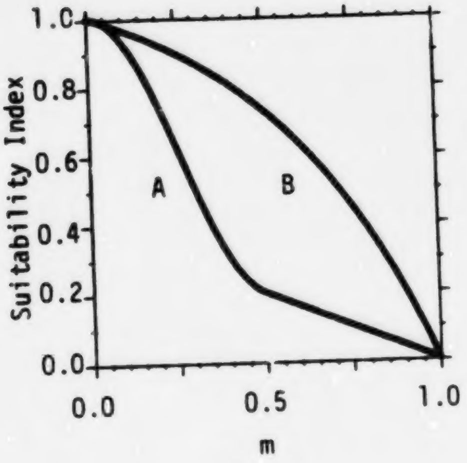
Appendix XXVII. Continued.

V_2

Drop in water level during embryo and fry stages.

A. Embryo and early fry stages (until yolk sac absorbed).
B. Fry stage, after yolk sac absorbed.

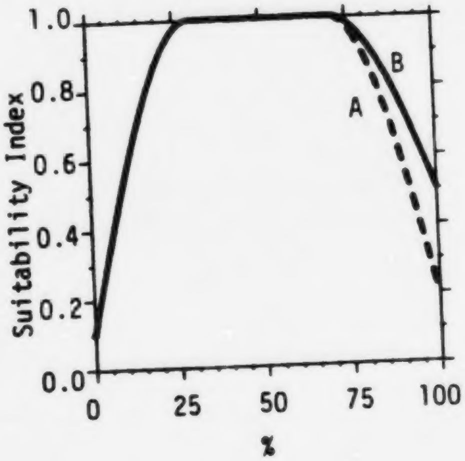
SI for V_2 = A or B, whichever is the lowest.



V_3

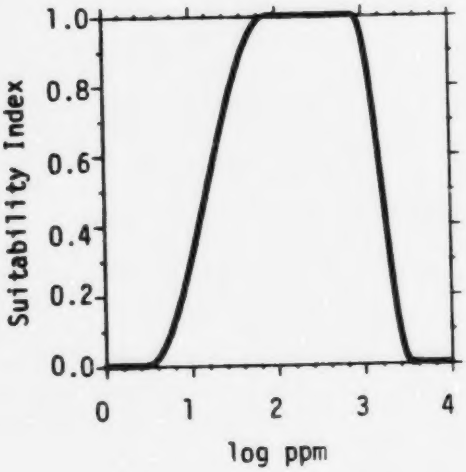
Percent of midsummer area with emergent or submerged aquatic vegetation or remains of terrestrial plants (bottom debris excluded).

A. Max. depth <3 m and lake ice-covered >2 months.
B. Max. depth >3 m or lake ice-covered ≤2 months, or both.

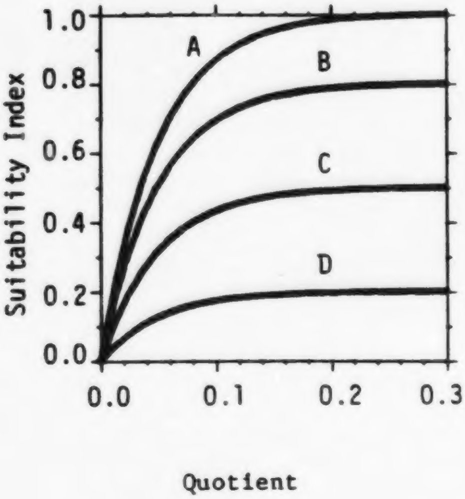


V_4

Logarithm (base 10) of total dissolved solids concentration of surface waters (1 to 2 m deep) during midsummer.



Appendix XXVII. Suitability Index graphs for the lacustrine HSI model variables for northern pike (from Inskip 1982).

Variable		Suitability graph
V_1	Ratio of spawning habitat to summer habitat (area that is less than 1 m deep and vegetated (spring), divided by total midsummer area).	

Use the appropriate curve, according to the density of vegetation or plant debris within the area included as spawning habitat. Do not include areas covered with filamentous algae, living or dead, as suitable spawning habitat.

A. Vegetation obscures most (>80%) of the bottom; plant material dense throughout the 15 cm of the water column above the substrate. When submersed, plant material not tightly compacted. Vegetation provides extensive surface area to which eggs may adhere, abundant cover for eggs and fry, and allows for circulation of water around the eggs (e.g. flooded sedge or grass meadow).

B. Plant growth less lush than in A, but covers much of the substrate and occupies much of water column directly above the sediments. More than 60% of the bottom obscured in vertical projection from depth of 15 cm above the bottom. Plant material not compacted when under water.

C. Vegetation or debris covers much of the bottom, but plant material does not occupy much of the water column immediately above the substrate. This category may include compacted vegetation, branches of woody plants, and leaves of deciduous trees.

D. Thinly scattered vegetation or debris only. Would provide little, if any, shelter for eggs and fry.

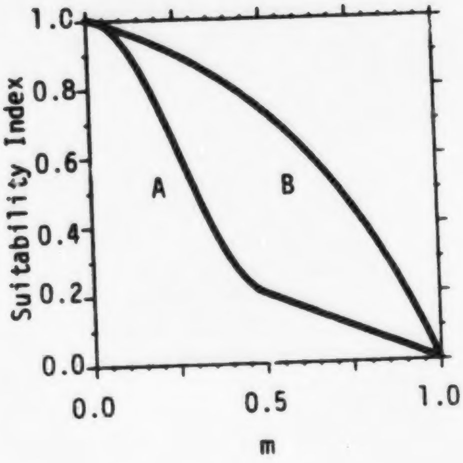
Appendix XXVII. Continued.

V_2

Drop in water level during embryo and fry stages.

A. Embryo and early fry stages (until yolk sac absorbed).
B. Fry stage, after yolk sac absorbed.

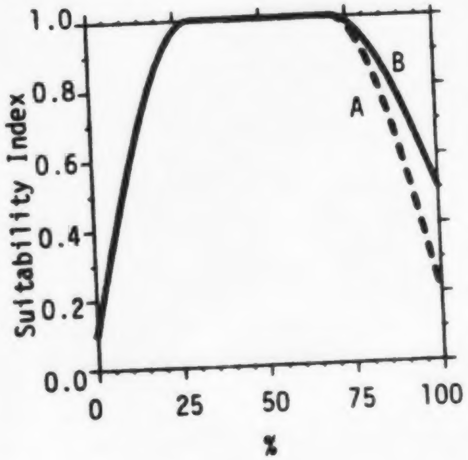
SI for V_2 = A or B, whichever is the lowest.



V_3

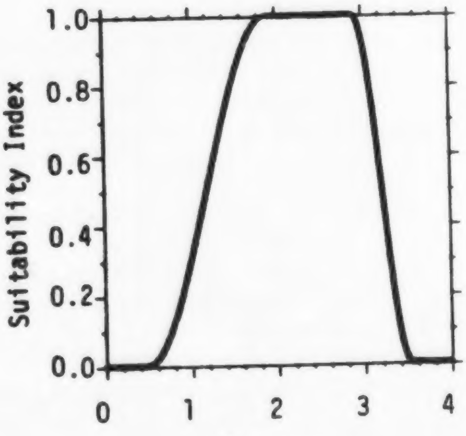
Percent of midsummer area with emergent or submerged aquatic vegetation or remains of terrestrial plants (bottom debris excluded).

A. Max. depth <3 m and lake ice-covered >2 months.
B. Max. depth >3 m or lake ice-covered ≤2 months, or both.



V_4

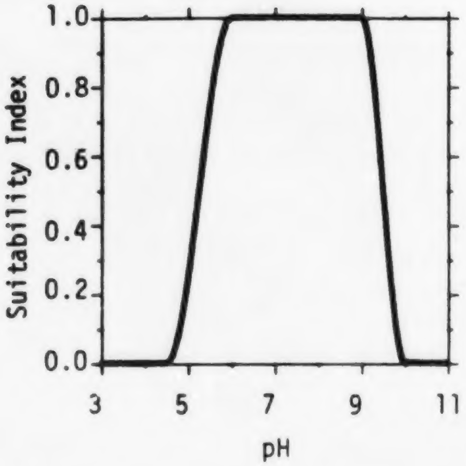
Logarithm (base 10) of total dissolved solids concentration of surface waters (1 to 2 m deep) during midsummer.



Appendix XXVII. Continued.

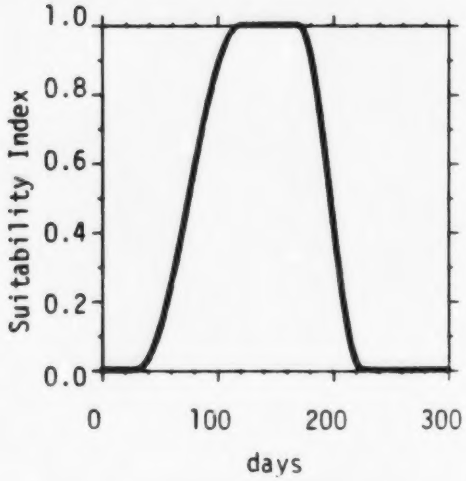
V_5

Least suitable pH in spawning habitat during embryo and fry stages.



V_6

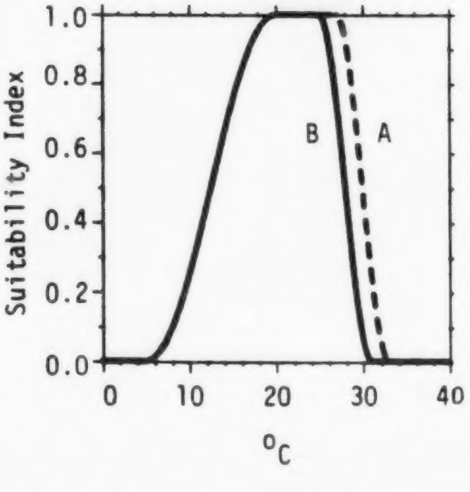
Average length of frost-free season (average number of days between last spring occurrence and first fall occurrence of an air temperature of 0°C).



V_7

Maximal weekly average temperature of the surface layer (1 to 2 m deep).

A. Stratified lake with >1.5 ppm dissolved oxygen in metalimnion.
B. River, stream, unstratified lake, or stratified lake with <1.5 ppm dissolved oxygen in metalimnion.



Appendix XXVIII. Daily Beamish net catches in Saskeram Lake from June 28 - August 6, 1984.

Date	YOY N. Pike	W. Sucker (Immat. or YOY)	Fathead Minnow	Five-spine Stickleback
June 29				
30				1
July 1				
2	8	4	38	117
3	3		73	86
4	1		39	52
5	(1*)	1	58	39
6	3	3	36	18
7	7		14	5
8	2		8	4
9		1	21	17
10	10		4	134
11	1			6
12	8		1	17
13	2		1	23
14				
15	9 (1*)		17	12
16	1 (1*)	(2$^+$)	49	38
17	4	(4$^+$)	46	33
18	4	(3$^+$)	12	87
19	4	(2$^+$)	2	21
20	7		16	7
21	5		18	8
22	4	(1$^+$)	2	33
23			17	8
24	3		6	13
25	2 (1*)		3	14
26			1	11
27		(1$^+$)	13	3
28	12		9	17
29	3			16
30	2		11	26
Aug. 5	7		2	11
6	2			
Totals	114 (4*)	9 (13$^+$)	517	877

(*) Adult pike

(+) YOY white sucker

Appendix XXIX. Results of Rotenone poison sets in the Saskeram Marshes, 1984.

Date	Location	Species Five-Spine Stickleback	 Fathead Minnow	 Northern pike YOY	 White suckers (Juvenile)
July					
10	Saskeram Lake	134	4	2	
	Birch R. Trappers Camp	46		3	
	Pyott's Crossing	300*		2	
17	Saskeram Lake			1	
	D/S Pyott's			10	
	Pyott's Crossing			6	
	U/S Pyott's			2	
18	D/S Elm Creek Control		30		
	Elm Creek outlet to Saskeram	40*	6		
22	U/S Pyott's	60*		1	1
23	Saskeram Lake	300*		3	
24	Saskeram Lake	150*			
25	Saskeram Lake	200*			
28	Saskeram Lake	200*	100*	4	
29	Saskeram Lake	200*	25		
30	Saskeram Lake	100*	100*		
Aug					
13	Pyott's Crossing			10	
23	Pyott's Crossing			8	
	Totals	1730*	265*	52	1

* Approximate numbers.

Appendix XXX. Counts made at Bracken Dam of forage fishes leaving the Saskeram Marshes for part of the openwater* period in 1984.

Date		Species		
		Fathead Minnow	Spottail Shiner	Five-Spine Stickleback
June	26-30	11		281
July	1-5	70		21
	6-10	39		
	11-15	597		
	16-20	101		1
	21-25	57		
	26-31	24		
Aug.	1-5	1009		
	6-10	386		
	11-15	399	8	
	16-20	407	13	
	21-25	731	13	
	26-31	115	18	1
Sept.	1-5	996	39	
	6-10			
	11-15	258	157	
	16-20	1	146	1
	21-25			
	26-30		31	
	Totals	5201	425	305

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* Freeze-up on Saskeram Lake occurred on October 25, 1984.

Appendix XXXIa. Dissolved oxygen results (Modified Winkler Method) from the Saskeram Marshes in 1983.

Station: Immediately above Bracken Dam

Date		mg/l			Comments
		Surface	Mid Depth	Bottom	
May	8	2.3			
	9	4.0			
	10	4.0			In fish ladder
	11	7.3			
	12	7.8			
	20	8.8			In fish ladder
	21	8.9			In fish ladder
	23	8.8			In fish ladder
July	2	7.1			
	17	7.0			
	30	4.9			
Aug.	5	2.9			
	8	3.6			
	13	4.8			
	23	11.8			
Sept.	2	7.3			
	28	10.9			
Oct.	15	12.1			
	26	13.6			
Nov.	9	12.0		12.2	
	18	11.8	11.7	11.6	
	20	10.4	10.1	8.6	
	22	10.8	10.5	10.2	
	24	10.4	10.0	8.8	
	30	10.7		10.7	
Dec.	2	8.0		10.3	
	4	9.5		7.7	
	6	6.0		4.1	
	9	3.4		3.2	
	11	2.7		3.6	
	13	1.9		0.3)	Smell of Hydrogen
	15	1.0		0.8)	sulphide present.

Appendix XXXIa. Continued.

Station: Below Bracken Dam

	mg/l			
Date	Surface	Mid Depth	Bottom	Comments
May 7	1.7			
11	7.3			
12	8.0			
Station: Carrot River				
May 8	9.4			Junction of Carrot and Birch Rivers
9	9.0			"
11	9.7		9.8	"
28	8.4			U/S Barge Crossing.
July 2	6.8			U/S Junction.
2	7.0			D/S Junction
Station: Saskatchewan River (Midstream) at Carrot River Entrance.				
May 9	10.0			
11	12.9			
28	10.8			
July 2	8.8			
Station: D/S Elm Creek Control Structure.				
Aug. 31	11.6			
Sept. 2	8.4			
Station: D/S Birch Lake Control Structure.				
Aug. 31	11.7			
Sept. 2	9.4			
Station: Saskeram Lake				
Aug. 23	12.5			
28	10.9			
Sept. 2	3.1			Sediment in water sample.

Appendix XXXIa. Continued.

Station: Saskeram Lake Outlet					
		mg/l			
Date		Surface	Mid Depth	Bottom	Comments
May	16	10.0			
	29	7.9			
July	2	3.0			
	17	4.3			
	23	5.4			
	30	1.3			
Aug.	5	0.9			
	8	1.7			
	13	2.3			
	23	3.9			
Sept.	2	1.8			
	28	7.0			
Oct.	15	8.3			
	26	6.7			
Station: Saskeram Lake Outlet					
Nov.	9	7.4	8.8		
Dec.	10	0.7	0.7		Indian Trapping Camp
	13	0.1	0.2		" " "
		0.6			
Station: Pyott's Crossing (Birch River)					
May	16	8.9			
	29	7.8			
July	2	5.2			
	17	6.1			
	23	4.4			
	30	3.4			
Aug.	5	1.2			
	8	2.6			
	13	4.5			
	23	11.6			
Sept.	2	4.2			
	28	10.9			

Appendix XXXIa. Continued.

Station: Pyott's Crossing (Birch River)

Date		mg/l Surface	Mid Depth	Bottom	Comments
Oct.	15	12.6			
	26	13.0			
Nov.	9	12.0		11.9	
Dec.	10	0.6		2.6	
	13	0.2		0.2	

Appendix XXXIb. Dissolved Oxygen test results (Modified Winkler Method) from the Saskeram Marshes in 1984.

Station: Immediately U/S Bracken Dam.					
	mg/1		Depth	Water	
Date	Surface	Bottom	m	Temp. C	Comments
April 18	6.4	6.4	2	6.00	
May 1	11.5	11.3	"	5.00	
July 3	6.2		"	20.75	
Aug. 14	6.5	6.6	"		
15	6.9	6.3	"		
18	7.9	6.2	"	22.00	
19	6.2	5.6	"	21.90	
20	5.9	5.5	"	21.00	
21	6.7	6.6	"	20.10	
22	7.0	6.9	"	19.75	
23	7.8	7.3	"	18.90	
Oct. 27	12.3	11.3	"	2.00	
29	11.0	10.8	"		
31	11.9	10.5	"		
Nov. 3	5.6	8.1	"		
6	6.3	4.0	"		
8	3.2	3.8	"		
11	1.6	1.5	"		
13	1.5	0.7	"		Stale smell.
15	1.7	0.5	"		Hydrogen suphide.
17	0.6	0.4	")		Decomposed pike in traps.
18	0.6	0.6	")		
19	0.6	0.1	")		Strong hydrogen sulphide odour present in dam.
20	0.3	0.1	")		
21	0.6	0.1	")		
Station: D/S Bracken Dam.					
April 18	7.4			6.00	
May 1	11.4			5.00	
17	8.95			14.95	
July 3	6.2			20.75	
Aug. 14	7.2	7.3	2		

Appendix XXXIb. Continued.

Date	mg/1 Surface	mg/1 Bottom	Depth m	Water Temp. C	Comments
Station: Saskeram Lake Outlet					
July 3	4.6			21.0	
Aug. 14	2.4	1.9	1		
15	2.3	1.3	"		
18	3.9	2.0	"		
19	1.9	2.3	"	20.0	
20	4.2	4.6	"		
21	4.2	4.3	"	17.0	
22	4.8	4.6	"	17.0	
23	5.3	5.1	"	17.0	
Station: Pyott's Crossing (Birch River)					
Aug. 14	2.4	1.9	1		
15	5.8	5.4	2		
18	6.4	3.9	2.5		
19	5.7	4.2	"	22.5	
20	6.0	5.6	"		
21	6.5	6.8	"	18.5	
22	6.9	6.8	"	19.75	
23	7.3	6.7	"	18.90	

Appendix XXXII. Chronological summary of observations on winterkills of fish in the Saskeram Marshes, 1980/81 to 1984/85.

Winter	Date	Location	Species	Remarks
#1 1980/81	February 25/81	Cumberland Dam D/S	Sticklebacks Juvenile pike Adult pike	- largest kill observed to date - estimated in thousands - advanced decomposition - substantial numbers of adult pike
	March 3/81	Birch Lake Control D/S	Sticklebacks Juvevile pike Adult pike	- pike appeared to be primarily juveniles - advanced decomposition
	March 3/81	Lake Six Control D/S	Juvenile pike	- completely frozen over with minimal leakage - however one pike observed on ice
#2 1981/82	December 14/81	Cumberland Dam D/S	no fish observed	- observations made during 0 monitoring program
	December 14/81	Birch Lake Control D/S	Stickleback Juvenile pike Adult pike White suckers Redhorse suckers	- primarily stickleback and juvenile pike - rough estimates of 8,000 - 10,000 fish - salvage permit issued to B. Cook who reported harvesting approx. 1,000 - 1,200 lbs of fish for trapline bait - advanced decomposition
	February 15/82	Cumberland Dam D/S	no fish observed	- observations made during Env. Can. 0 survey.
	March 8/82	Bracken Dam U/S	Sticklebacks Juvenile pike Adult pike White suckers	- very extensive kill with no estimate of numbers - juvenile pike were primary species evident - walleye were reported observed but never confirmed
		D/S	no fish observed	

Appendix XXXII. Continued.

Winter	Date	Location	Species	Remarks
#3 1982/83	December 14/82	Cumberland Dam D/S	Sticklebacks Juvenile perch	- relatively minor - no pike observed
	December 14/82	Birch Lake Control D/S	Sticklebacks Juvenile pike White suckers	- largest kill estimated at 36,000 to 72,000 fish (block counts through ice) - salvage permit issued (B. Cook) but not record submitted - primarily sticklebacks and juvenile pike
	December 14/82	Lake Six Control D/S	Stickleback Juvenile pike Adult pike White suckers	- primarily sticklebacks
#4 1983/84	December 22/83	Birch Lake Control D/S	Stickleback Juvenile pike	
	December 22/83	Lake Six Control D/S	Stickleback Juvenile pike	
	January 18/84	Cumberland Dam D/S	(see remarks)	- large number of surviving pike netted downstream of dam
		Birch Lake Control D/S	Stickleback Juvenile pike	
	January 18/84	Lake Six Control D/S	Stickleback Juvenile pike	
	January 18/84	Elm Creek Control D/S	Sticklebacks	

Appendix XXXII. Continued.

Winter	Date	Location	Species	Remarks
#4 (continued)				
1983/84	February 24/84	Cumberland Dam D/S	Sticklebacks Juvenile pike Adult pike	- observed during O_2 monitoring survey - kill occurred sometime between February 13 - 19 - differs from other kill areas in that adult pike represented a larger portion of kill
		Birch Lake Control D/S	Sticklebacks Juvenile pike	
		Lake Six Control D/S	Sticklebacks Juvenile pike	
#5 1984/85	November 22/84	Birch Lake Control D/S	Stickleback Juvenile pike Adult pike White suckers	- salvage permit issued to B. Cook who reports approximately 500 - 800 pounds of fish used for trapline bait to date.
	February 20/85	Cumberland Dam D/S	Sticklebacks Juvenile pike Adult pike	- fishkill consisted of several thousand juvenile pike and a few adult pike

Appendix XXXIIIa. Winter dissolved oxygen testing in the Saskeram Marshes, February 28, 1981.

Investigator: B. H. Wright, Fisheries Branch, Northwest Region, The Pas.

Method: Surface water samples were collected from holes drilled through the ice and analyzed with Hach dry chemicals using the modified Winkler method. See Fig. 16. for sample locations.

Location	Depth(cm)		
	Ice	Water	DO_2(mg.$^{-1}$)
1. U/S Carrot River	54	271	6.0
2. U/S Bracken Dam	67	251	0
3. D/S Pyott's Crossing	91	195	0
4. U/S Pyott's Crossing	63	288	0
5. D/S Saskeram L. outlet	74	195	0
9. Birch Lake	95	44	0
10. Birch L. inlet	88	26	0
18. 5 km U/S Birch L. inlet	53	191	0

Note: Three additional sites were sampled in each of the upper and lower sections of the Birch River. The odour of hydrogen sulphide gas was evident at all the Saskeram Marshes sampling sites. It is suspected that winterkill would have been complete at this time.

Appendix XXXIIIb. Dissolved oxygen testing in the Saskeram Marshes during the 1981/82 winter season.

Investigator: D. Leroux, Fisheries Branch, Northwest Region, The Pas.

Method: Same as on February 28, 1981.

Location	DO2 ($mg \cdot l^{-1}$) on - 14-12-81	15-2-82	7-4-82
1. U/S Carrot River	5.3	8.5	2.2
2. U/S Bracken Dam	6.2	0.6	0.2
3. D/S Pyott's Crossing	2.1	0.2	1.6
4. U/S Pyott's Crossing	0.8	0.2	0.6
5. 1.5 km D/S Saskeram outlet	0.3	0	0.6
6. Saskeram Lake	11.0	0	0
7. D/S Elm Creek control	2.1	0	0
8. U/S Elm Creek control	0.4	0	0
9. Birch Lake	2.3	0	0.2
10. Birch Lake inlet	1.7	0.3	0
11. U/S Cumberland Dam	2.3	0	0
12. D/S Cumberland Dam	4.1	0.6	0.6
13. U/S Birch Lake control	0.7	0	0.4
14. D/S Birch Lake control	1.0	0.1	0.6
16. U/S Lake Six control	0.7	0.3	0.4
17. D/S Lake Six control	0.9	0.1	2.0

Note: Fishkill starting during 14-12-81 sampling. Thousands of stressed juvenile pike were noted on the D/S side of Birch Lake control. A complete winterkill apparent by 15-2-82.

Appendix XXXIIIc. Dissolved oxygen testing immediately downstream of Cumberland Dam in the fall and winter 1982/83.

Investigator: Saskatchewan Parks and Renewable Resources and Ducks Unlimited (Canada) staff, Cumberland House, Sask.

Method: Same as previous.

Location	$DO_2 (mg \cdot l^{-1})$ on - 25-10-82	25-11-82	12-1-83
12. D/S Cumberland Dam	9.7	9.4	4.5

Note Several patrols were made to the area and live fish were observed below Cumberland Dam until mid December, when some mortality of sticklebacks and juvenile yellow perch and white suckers was noted. Four pike (approx. 0.68 kg) were gillnetted on December 13. By January 19, 1983, pike ranging in size from 15-30 cm. as well as juvenile perch and sticklebacks were dying. From February 16 to March 30, the openwater area below the dam increased in size and water quality likely improved, although "stagnant odour and froth" were still evident. No fish, alive or dead, were observed in the March 30 patrol.

Appendix XXXIIId. Winter dissolved oxygen testing in the Saskeram Marshes on January 17 - 18, 1984.

Investigator: D. Gillies, Fisheries Branch, Winipeg.

Method: Collection of surface and bottom water samples with a Kemmerer water sampler. Oxygen analysis made with freshly prepared chemicals using the modified Winkler method. See Fig. 16 for sample locations.

Location	Depth (cm) Ice	Depth (cm) Water	DO_2 ($mg.l^{-1}$) Surface	DO_2 ($mg.l^{-1}$) Bottom
1. U/S Carrot River	36	203	0.7	0.5
2. U/S Bracken Dam	64	257	0.1	0
3. D/S Pyott's Crossing	44	100	0.6	0.6
5. 1.5 km D/S Saskeram L. outlet	37	234	0	0
6. Saskeram L.	70	Frozen	N.S.	N.S.
7. D/S Elm Creek Control	32	181	0	0
8. U/S Elm Creek Control	56	119	0	0
9. Birch Lake	68	80	4.2	3.4
10. Birch Lake inlet	50	60	0.7	0
11. U/S Cumberland Dam	42	333	4.5	2.9
12. D/S Cumberland Dam	34	264	7.1	3.5
13. U/S Birch Lake Control	42	82	0	0
14. D/S Birch Lake Control	45	3	0.3	N.S.
15. Lower Birch River	54	286	0.2	0
16. U/S Lake Six Control	46	151	0	0.2
17. D/S Lake Six Control	17	108	0.1	0

N.S. = No Sample

Note: Dead fish were observed downstream of Elm Creek control (sticklebacks), U/S and D/S of Birch Lake Control (juvenile Pike and D/S of the Lake six Control (juvenile pike). Live sticklebacks were observed D/S of the Birch Lake and Lake Six Controls. There was approximately one square metre of open water D/S of the Lake Six Control. Gillnetting below Cumberland Dam showed an overwintering population of pike; 285 juveniles, 7 adults were netted overnight. One juvenile white sucker was also noted in the catch. Gillnetting was done at Pyott's Crossing, but the nets was frozen into the ice and could not be lifted. Subsequent retrieval of the net in April showed no evidence that fish had been caught in the net.

Appendix XXXIIIe. Winter dissolved oxygen testing in the Saskeram Marshes on February 21 and 23, 1984.

Investigator: D. Leroux, Fisheries Branch, Northwest Region, The Pas.

Method: Collection of surface and bottom water samples using a Kemmerer sampler. Oxygen analysis made with Hach dry chemicals using the modified Winkler method.

Location	Depth (cm)		DO_2 $mg \cdot l^{-1}$	
	Ice	Water	Surface	Bottom
1. U/S Carrot River	71	173	0.2	0.2
2. U/S Bracken Dam	91	305	0	0
3. D/S Pyott's Crossing	76	213	0	0
5. Birch Lake	89	25	0	N.S.
10. Birch L. inlet	90	32	0	N.S.
11. U/S Cumberland Dam	93	242	0.8	0
12. D/S Cumberland Dam*	86	462	5.2	0
13. U/S Birch L. Control	63	62	0	N.S.
14. D/S Birch L. Control	76	18	0	N.S.
16. U/S Lake Six Control	79	103	0.1	0
17. D/S Lake Six Control	41	96	0	N.S.
18. Upper Birch River	72	172	0.4	0.6

N.S. = No Sample. * Approx. 50 m D/S of dam.

NOTE: Dead fish were observed at each control structure. A large fish kill had occurred at Cumberland Dam with pike, ranging in weight from 0.25 to 3.0 kg, comprising the bulk of the dieoff. High oxygen level below Cumberland Dam appeared to be the result of openwater. Openwater was not present when Ducks Unlimited personnel visited the site just prior to this sampling.

Appendix XXXIIIf. Winter dissolved oxygen testing at Cumberland Dam on February 20, 1985.

Investigator: D. Leroux, Fisheries Branch, Northwest Region, The Pas.

Method: Surface midwater and bottom samples were collected with a Kemmerer water sampler. Oxygen analysis made with Hach dry chemicals using the modified Winkler method. See Fig. for sample locations.

	Location	Depth (cm)			DO_2 ($mg \cdot l^{-1}$) at		
		Ice	Water	Snow	Surface	Mid.	Bottom
11.	U/S of dam	63	300	21	-	0	-
12.	50 m D/S of dam	49	450	20	2.6	3.2	0
19.	200 m D/S of dam	66	450	12	4.0	4.0	0
20.	700 m D/S of dam	54	250	35	S.B.	S.B.	1.8
21.	1200 m D/S of dam	55	400	33	0.4	-	0.1
-	Openwater below dam	-	-	-	-	5.6	-

S.B. Sample bottle broke.

NOTE: A fishkill consisting of several thousand juvenile pike had taken place. A few dead adult pike also were observed, as well as many dead sticklebacks. Some colour had developed in those sample bottles which broke, which indicated there was some oxygen present in the samples. The high oxygen levels recorded were probably due to the stretch of openwater immediately D/S of Cumberland Dam.